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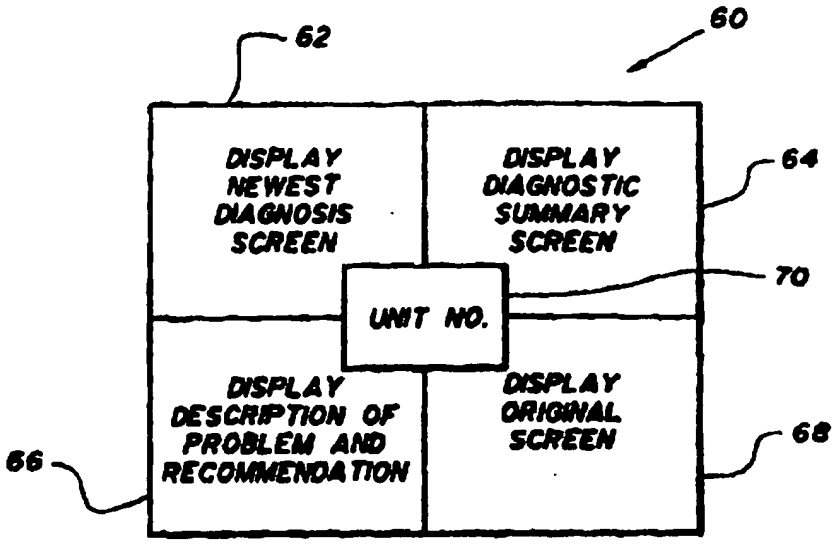
(57) Abstract

A diagnostic advisor that performs two main functions - diagnostic and control - is disclosed. In association with the diagnostic function, the diagnostic advisor helps the operator quickly take appropriate action through startup, operation and shutdown of a remote generating facility. In association with the control function, the diagnostic advisor provides an efficient interface between the operator and the system. When a malfunction is detected, the diagnostic advisor immediately displays a malfunction icon on whatever screen is currently being displayed. The icon alerts the operator that a malfunction has occurred or is immanent. An expert system automatically processes monitored information and compiles a diagnostic analysis and a list of one or more recommended options. The diagnostic advisor allows the operator to view a list of probable diagnoses, to view a recommended information screen that best shows the problem variables identified by the diagnostic advisor, or to continue viewing the current screen. The control function of the diagnostic advisor allows the operator to select for viewing, at any time, a recommendation screen, an option menu, the previous screen, or a summary screen.



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DIAGNOSTIC ADVISOR FOR COMBUSTION TURBINE OPERATIONS

The present invention relates generally to a computer-implemented process and system for providing information to an operator of a complex system. More particularly, the present invention relates to a computer-implemented "Diagnostic Advisor" for providing information in an optimal manner to an operator of a combustion turbine plant.

BACKGROUND OF THE INVENTION

One preferred application of the present invention is in connection with the operation of a combustion turbine plant and more particularly in connection with the remote operation of a combustion turbine plant. Therefore, the background of the invention and preferred embodiments of the invention are described below with reference to a system for remotely controlling a combustion turbine plant. It should be understood, however, that the present invention is by no means limited to applications involving the operation of a combustion turbine plant. Accordingly, except where they may be expressly so limited, the scope of protection of the claims at the end of this specification is intended not to be limited to applications of the invention involving combustion turbines.

The assignee of the present invention (Westinghouse Electric Corporation) employs remote startup equipment at its Orlando, Florida Diagnostic Operations Center to start three combustion turbines located in Virginia. The remote startup capability allows the local utility to provide continuous power to its customers after regular business hours without

staffing the plant 24 hours a day. Upon receiving a request from the plant operator, the remote Diagnostic Operations Center can start the combustion turbines remotely, providing full unit power within minutes (e.g., 45 minutes) of the request.

The system described above is schematically depicted in Figure 1 and is discussed in greater detail below in connection with the detailed description of preferred embodiments of the present invention. Briefly, the Diagnostic Operations Center employs a microprocessor-based system including graphics and communications cards. The system transmits and receives data over telephone lines with the use of modems and multiplexers. The turbine plant operators can transfer control of the plant to the Diagnostic Operations Center operators by turning a switch on a keyboard. The transfer of control enables the Diagnostic Operations Center operators to start the turbines remotely and to remotely manipulate the plant breakers to supply power to all equipment, as necessary. It typically takes approximately 14 minutes from startup to generator synchronization for each unit and 10 more minutes to bring each unit to full load. The power demanded by the starting motors is typically too high to allow all of the turbines to be started at once. Therefore, the turbines are typically started sequentially. Accordingly, the Diagnostic Operations Center operator must carefully sequence the startups to meet the prescribed (e.g., 45 minute) requirement for bringing all turbine units to full load.

There are a number of advantages offered by this system. For example, the Diagnostic Operations Center's remote startup capability allows Westinghouse to provide 24-hour coverage and 45-minute availability of the plant's full output to meet the local community's variable load demands, although the plant is not staffed 24 hours a day. In addition, the Diagnostic Operations Center's remote startup capability enables Westinghouse to receive immediate notification of any event that might prevent the plant from

responding to a dispatch call, and to review combustion turbine operating data on-line to verify operating parameters and equipment status.

Notwithstanding its advantages, there are several problems with this system. For example, there are various screen displays that are used to present information to the operator. Currently, the operator must know (through training or experience) which screen best displays the information needed. For example, in one embodiment of the system, the necessary information is displayed on twenty-three different screens which are entirely filled with data and graphic displays. Screens must be viewed in the proper sequence for successful unit operation. Several screens display overlapping information about the same system. For example, some vibration data is shown on five different screens. Considerable knowledge is required by the operator to find the screen that best accesses specific information. Furthermore, during startup of peaking units, the operator is focused on starting up multiple units together in a contractually specified period of time. The operator must stay alert to an overwhelming amount of data. For example, alarms sound to signal that normal steps are taking place. During this time, the visible screen is the startup screen for the current unit and twenty-two other screens are not visible. The operator may be distracted from watching the screens for the other units. If a malfunction occurs, the operator may be unaware of it. When aware of a problem, the operator must rely on experience to know which screen will best show the most important and useful information. Lack of information about a malfunction can have serious consequences. For example, lubricating oil may be lost, a blade may be lost, a combustor basket may be burned, a transition tube may collapse, or the temperature of a rotor cavity may become too high as a consequence of the operator being overwhelmed by the plethora of information available. Therefore, it is extremely important to present the operator the information most useful

to him for dealing with any problems that might arise, and to do so immediately.

SUMMARY OF THE INVENTION

Briefly, the present invention provides a diagnostic advisor that performs two main functions -- diagnostic and control. In association with the diagnostic function, the diagnostic advisor provides a means for helping the operator quickly take appropriate action through startup, operation, and shutdown. In association with the control function, the diagnostic advisor provides a convenient and efficient interface between the operator and the system.

In the preferred embodiment of the invention described herein below, the diagnostic advisor immediately displays a malfunction icon on whatever screen is currently being displayed. The icon, which is coded to identify the unit or system involved, alerts the operator (for example, by blinking and/or by employing a color code) that a malfunction has occurred or is immanent. In addition, an expert system automatically processes monitored information and compiles a diagnostic analysis and a list of one or more recommended options. The diagnostic advisor allows the operator to view a list of probable diagnoses (which is also a menu to a best monitoring information screen for each diagnosis), to view a recommended information screen that best shows the problem variables identified by the diagnostic advisor, or to continue viewing the current screen. The control function of the diagnostic advisor allows the operator to select for viewing, at any time, a recommendation screen, an option menu, the previous screen viewed, or a diagnostic summary screen.

The present invention provides a system for alerting the operator to a malfunction immediately. In addition, the inventive system immediately informs the operator what and where the problem is and how urgent it is. The invention also makes an expert system available to advise the operator of a list of one or more best action options. The invention provides a way of giving an experienced operator immediate, expert corroboration, which allows the operator to act more

quickly. The present invention also provides a continuous training tool, since the expert system feature of the diagnostic advisor continuously teaches the operator or user, which keeps even experienced operators well-trained. The invention also provides a means for improving plant availability, and saving costs in contractual failure-to-startup penalty fees. (For example, for peaking units, the penalty can be $15,000 per startup time period failure). Moreover, the present invention provides a means for saving costs in operation damage, including repair expenses and costs associated with the loss of a unit for down time. (For example, opening and closing a unit for repair can cost approximately $1,000,000).

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a block diagram of one preferred embodiment of the present invention.

Figures 2A through 2S depict various screen displays provided by the system.

Figure 3 is a schematic diagram of a diagnostic advisor in accordance with the present invention.

Figure 4 is a depiction of a malfunction icon in accordance with the present invention.

Figure 5 is a depiction of a diagnostic summary screen in accordance with the present invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

Figure 1 schematically depicts one preferred embodiment of a combustion turbine monitoring and control system in accordance with the present invention. The system comprises a plurality of generators 10 and associated combustion turbines 12. The generators and turbines are respectively connected to data links 14, 16 coupled to a data highway 18. The data highway 18 provides access to a variety of monitored parameters associated with the generators and turbines from a control room 20. The control room houses a computer/console 22, which is coupled to a modem 24. The modem 24 is coupled to a phone line 26, which in turn is

coupled to a modem 28 and computer/console 30 at a remote location.

According to the present invention, a software-implemented diagnostic advisor 40 manages the presentation of information and screen displays to the operator viewing the remote console 30. Before describing the functionality of the diagnostic advisor 40, a brief review of the various screens which may be presented or available for presentation to the remote operator will be provided.

Figure 2A depicts an exemplary startup screen. In particular, this screen is a "Unit No. 1 -- Selection Screen." As shown, this screen includes a master run field, a speed control field, a temperature control field, a power factor control field, a water injection control field, two breaker control fields, and so on. These various fields provide an interface to the operator for use in controlling various operations of the combustion turbine unit in question, which in this case is Unit No. 1. The meanings of the various terms presented in this screen display and the other screen displays discussed below are not described in detail in this specification, since such meanings will be apparent to those skilled in the art.

Figure 2B depicts a "Combustion Turbine Longitudinal" screen for combustion turbine unit No. 1. As shown, this screen depicts a variety of information. For example, the displayed information relates to inlet air temperature and pressure; air flow velocity; blade valves; blade path temperatures; exhaust gas temperature, and so on.

Figure 2C depicts a "Trip Screen" providing information regarding a number of breakers associated with combustion turbine unit No. 2.

Figure 2D depicts a "Fuel Oil Supply System" screen providing information regarding the fuel oil supply system of combustion turbine unit No. 1. It should be noted in connection with this screen and the other screens that there will often be overlap with respect to the subsystem-related information provided by the various screens. For example, the

"fuel oil supply system" screen and a number of other screens display information regarding blade path temperature.

Figure 2E depicts a "Gas Fuel System" screen displaying information regarding the gas fuel system for combustion turbine unit No. 2.

Figure 2F depicts a "Lube Oil System" screen.

Figure 2G depicts a "Hot Gas Path" screen.

Figure 2H depicts an "Overall-Start to Synchronization" screen.

Figure 2I depicts a "Turbine Functions" screen.

Figure 2J depicts a "Combustion Cycle-Power Generation Mode" screen.

Figure 2K depicts a "Overall - 89% speed to full power" screen.

Figure 2L depicts a "Generator Jacking/Lube Oil System" screen.

Figure 2M depicts a "BOP Protective Relay Alarms" screen.

Figure 2N depicts a "AUX Power Overview" screen.

Figure 2O depicts a "Transformer Alarms" screen.

Figure 2P depicts a "Remote Operation Overview" screen.

Figure 2Q depicts a "13.8 KV System Overview" screen.

Figure 2R depicts a "Fuel Forwarding Overview" screen.

Figure 2S depicts a "Water Injection System" screen.

From the above brief review of the various screens for presentation to the operator, it is apparent that both experienced and inexperienced operators will often become overwhelmed by the plethora of information available. The present invention provides a computer-implemented process for coordinating and managing the presentation of information to the operator so that he or she will be able to most effectively use the information available.

Figure 3 schematically depicts the features of the diagnostic advisor software in accordance with the present

invention. As shown, the diagnostic advisor 40 comprises a diagnostic component and a control component. The diagnostic component includes a component 42 for displaying a malfunction icon (see Figure 4); an expert system component 44 for analyzing the monitored information and providing a diagnosis or a list of possible diagnoses of any malfunctions that arise; a component 46 for alerting the operator of any problems or malfunctions; and a component 48 for advising the operator of one or more best action options. The control component includes an operator interface 50 for switching screens and selecting options.

Referring now to Figure 4, one embodiment of the present invention provides a malfunction icon 60 whenever a malfunction is detected. The malfunction icon 60 is displayed on the operator's console along with whatever screen display is currently being viewed. The malfunction icon 60 includes a plurality of fields, including a first field 62, a second field 64, a third field 66, and a fourth field 68. In addition, in a central region 70 the unit number or some other identification of the combustion turbine unit in question is displayed. As indicated in the figure, the first field 62 provides a means whereby the operator may instruct the system to display the newest diagnosis screen. The second field 64 provides a means whereby the operator may instruct the system to display a diagnostic summary screen (Figure 5). The third field 66 provides a means whereby the operator may instruct the system to display a description of the problem or problems detected and a recommendation as to the appropriate action for the operator to take. The fourth field 68 allows the operator to instruct the system to display, or go back to, an original screen, which may be any pre-specified screen in a series of screen displays. Preferably, when the operator selects the third field 66, the system will not only display a description of the detected problem and the appropriate action to take in response thereto, but will also display a description of what will happen if the recommended action is not taken.

Figure 5 depicts an exemplary diagnostic summary screen 80. As shown, the diagnostic summary screen will preferably include a first field 82 for displaying the identification of the unit number in question. In addition, the diagnostic summary screen preferably will include another field 84 for displaying a confidence factor for the respective diagnoses, which are displayed in order of importance and/or color coded in a third field 86.

WE CLAIM:

1. A computer-implemented process for providing information to an operator of a system comprising one or more machines and a monitoring system, said monitoring system including means for measuring a plurality of parameters and presenting a plurality of screen displays each representing one or more of said parameters, the process comprising the steps of:

(a) maintaining for each machine a list of one or more diagnoses based upon measured parameters corresponding to that machine;

(b) presenting an icon to the operator, said icon indicating a possible malfunction and comprising plural fields, each field allowing the operator to select an action; and

(c) automatically determining the most relevant screen display corresponding to at least one of said diagnoses and displaying said most relevant screen display.

2. A process as recited in claim 1, wherein a first field of said icon, when selected, causes the system to display a diagnosis of a malfunction of said machine.

3. A process as recited in claim 2, further comprising displaying a list of diagnoses and a confidence level for each diagnosis in said list.

4. A process as recited in claim 1, wherein at least one of the machines is a combustion turbine.

5. A process as recited in claim 3, wherein at least one of the machines is a combustion turbine.

6. A process as recited in claim 1, wherein the process comprising steps a through c is performed remotely from the system being monitored.

7. A process as recited in claim 5, wherein the process comprising steps a through c is performed remotely from the system being monitored.

8. A computer-implemented process for providing information to an operator of a system comprising one or more machines, comprising the steps of:

(a) monitoring said machine to obtain measurements of a plurality of parameters;

(b) presenting a plurality of screen displays each representing one or more of said parameters;

(c) maintaining for each machine a list of one or more diagnoses based upon measured parameters corresponding to that machine; and

(d) automatically determining the most relevant screen display corresponding to at least one of the diagnoses and displaying said most relevant screen display.

9. A process as recited in claim 8, further comprising the step of displaying an icon, said icon signalling a malfunction and comprising plural fields, each field allowing the operator to select an action.

10. A process as recited in claim 9, wherein a first field of said icon, when selected, causes the system to display a diagnosis of a malfunction of said machine.

11. A process as recited in claim 10, further comprising displaying a list of diagnoses and a confidence level for each diagnosis in said list.

12. A process as recited in claim 11, wherein at least one of the machines is a combustion turbine.

13. A process as recited in claim 12, wherein the process is performed remotely from the machine being monitored.

14. A system for providing information to an operator of one or more machines, comprising:

(a) means for monitoring said machine to obtain measurements of a plurality of parameters;

(b) means for presenting a plurality of screen displays each representing one or more of said parameters;

(c) means for maintaining for each machine a list of one or more diagnoses based upon measured parameters corresponding to that machine; and

(d) means for automatically determining the most relevant screen display corresponding to at least one of the diagnoses and displaying said most relevant screen display.

15. A system as recited in claim 14, further comprising means for displaying an icon, said icon signalling a malfunction and comprising plural fields, each field allowing the operator to select an action.

16. A system as recited in claim 15, wherein a first field of said icon, when selected, causes the system to display a diagnosis of a malfunction of said machine.

17. A system as recited in claim 16, further comprising means for displaying a list of diagnoses and a confidence level for each diagnosis in said list.

18. A system as recited in claim 17, wherein at least one of the machines is a combustion turbine.

19. A system as recited in claim 18, wherein the system remotely connected to the machine being monitored.

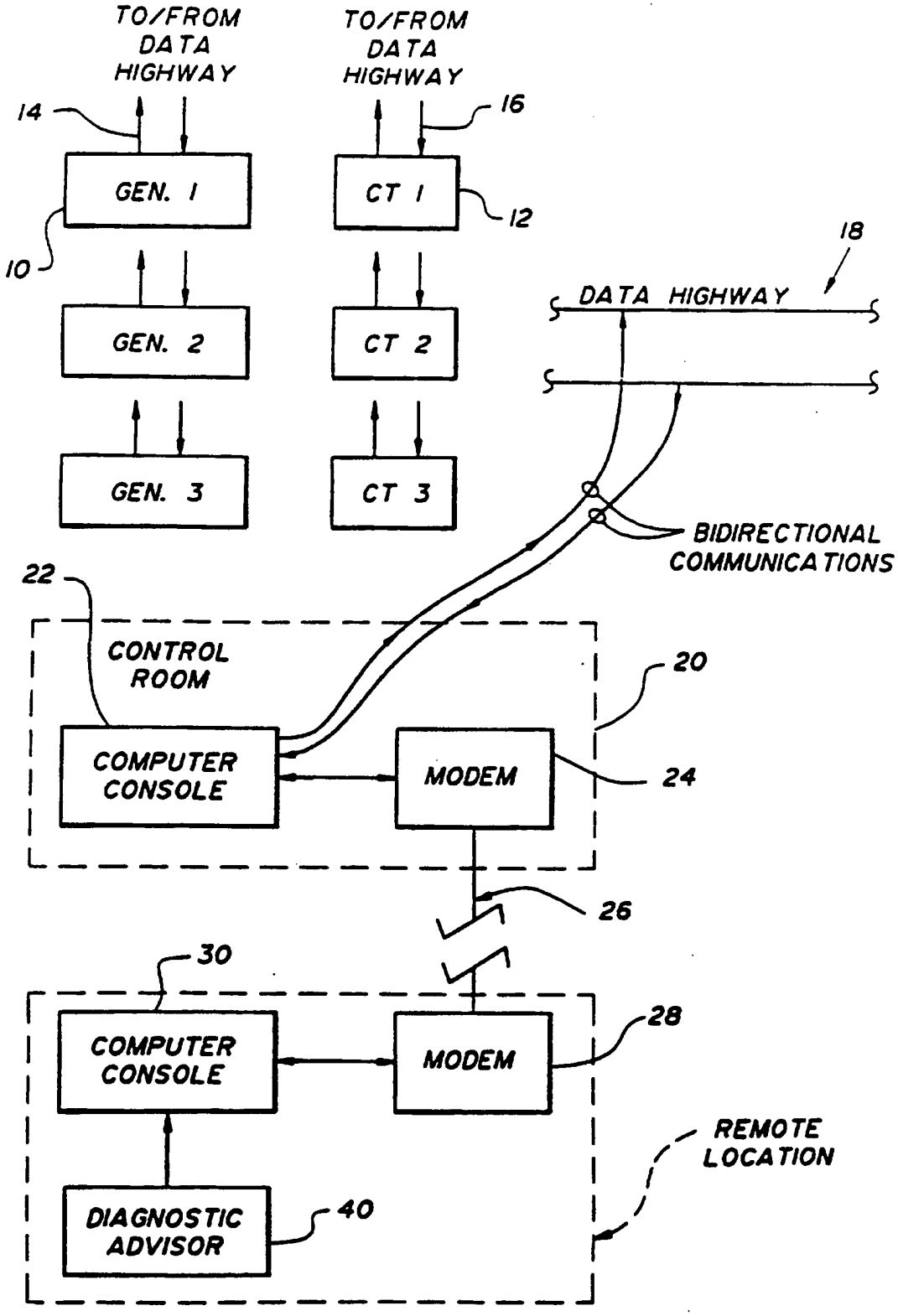
TO/FROM DATA HIGHWAY
TO/FROM DATA HIGHWAY
14
16
GEN. 1
CT 1
12
10
GEN. 2
CT 2
GEN. 3
CT 3
18
DATA HIGHWAY
BIDIRECTIONAL COMMUNICATIONS
22
CONTROL ROOM
20
COMPUTER CONSOLE
MODEM
24
26
30
COMPUTER CONSOLE
MODEM
28
REMOTE LOCATION
DIAGNOSTIC ADVISOR
40

FIG. 1

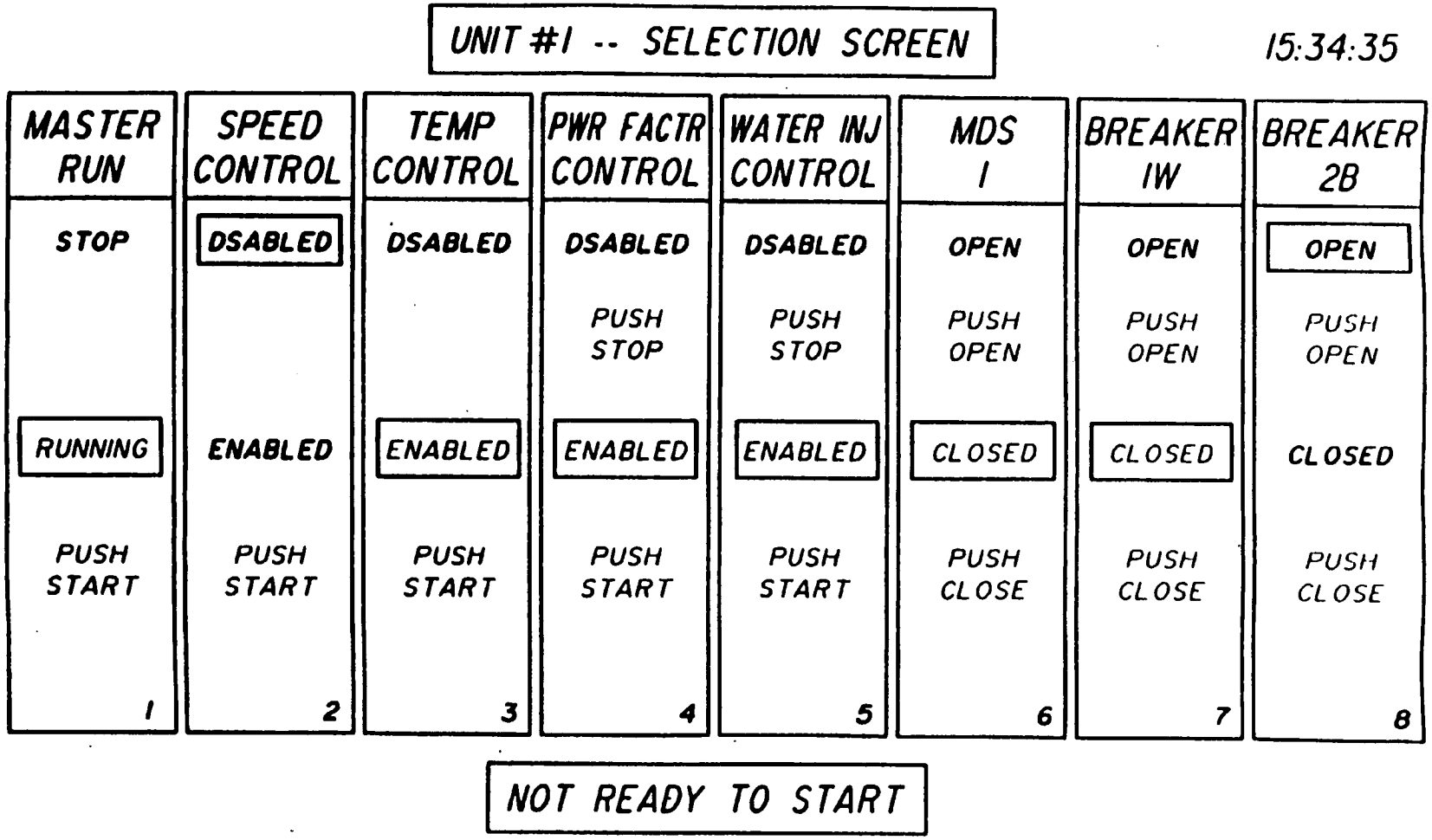
UNIT #1 -- SELECTION SCREEN
15:34:35
MASTER RUN
SPEED CONTROL
TEMP CONTROL
PWR FACTR CONTROL
WATER INJ CONTROL
MDS 1
BREAKER 1W
BREAKER 2B
STOP
DSABLED
DSABLED
DSABLED
DSABLED
OPEN
OPEN
OPEN
PUSH STOP
PUSH STOP
PUSH OPEN
PUSH OPEN
PUSH OPEN
RUNNING
ENABLED
ENABLED
ENABLED
ENABLED
CLOSED
CLOSED
CLOSED
PUSH START
PUSH START
PUSH START
PUSH START
PUSH START
PUSH CLOSE
PUSH CLOSE
PUSH CLOSE
1
2
3
4
5
6
7
8
NOT READY TO START

FIG. 2A

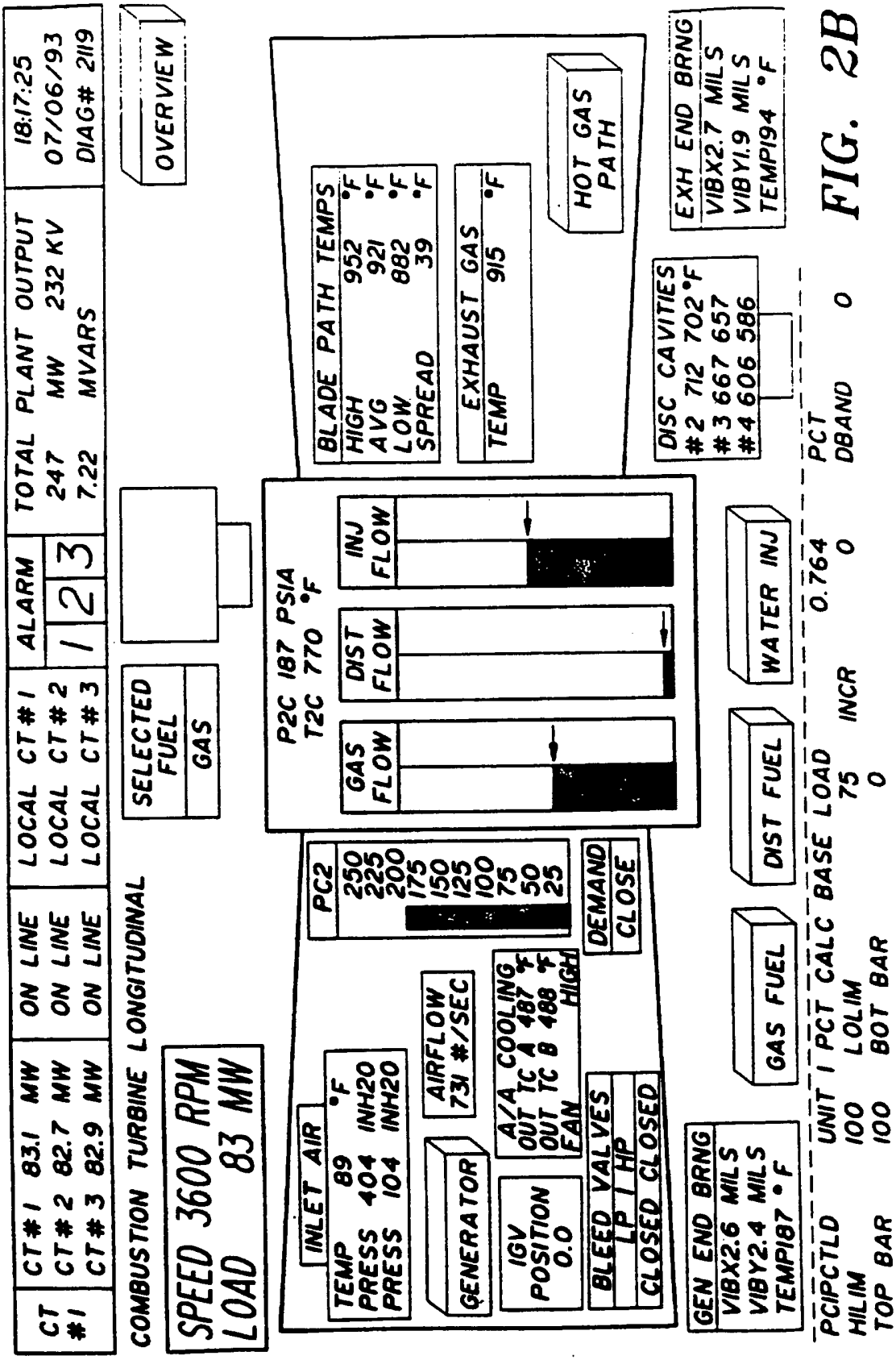
CT #1
CT#1 83.1 MW
CT#2 82.7 MW
CT#3 82.9 MW
ON LINE
ON LINE
ON LINE
LOCAL CT#1
LOCAL CT#2
LOCAL CT#3
ALARM
1 2 3
TOTAL PLANT OUTPUT
247 MW 232 KV
7.22 MVARS
18:17:25
07/06/93
DIAG# 2119
OVERVIEW
COMBUSTION TURBINE LONGITUDINAL
SPEED 3600 RPM
LOAD 83 MW
SELECTED FUEL
GAS
P2C 187 PSIA
T2C 770 °F
GAS FLOW
DIST FLOW
INJ FLOW
BLADE PATH TEMPS
HIGH 952 °F
AVG 921 °F
LOW 882 °F
SPREAD 39 °F
EXHAUST GAS
TEMP 915 °F
HOT GAS PATH
DISC CAVITIES
#2 712 702 °F
#3 667 657
#4 606 586
EXH END BRNG
VIBX2.7 MILS
VIBY1.9 MILS
TEMP194 °F
INLET AIR
TEMP 89 °F
PRESS 404 INH20
PRESS 104 INH20
PC2
250 225 200 175 150 125 100 75 50 25
AIRFLOW
731 #/SEC
GENERATOR
A/A COOLING
OUT TC A 487 °F
OUT TC B 488 °F
FAN HIGH
IGV
POSITION
0.0
DEMAND
CLOSE
BLEED VALVES
LP / HP
CLOSED CLOSED
GEN END BRNG
VIBX2.6 MILS
VIBY2.4 MILS
TEMP187 °F
GAS FUEL
DIST FUEL
WATER INJ
PCIPCTLD 0.764
HILIM 100 LOLIM 75 INCR 0
TOP BAR 100 BOT BAR 0
UNIT 1 PCT CALC BASE LOAD
PCT
DBAND 0

FIG. 2B

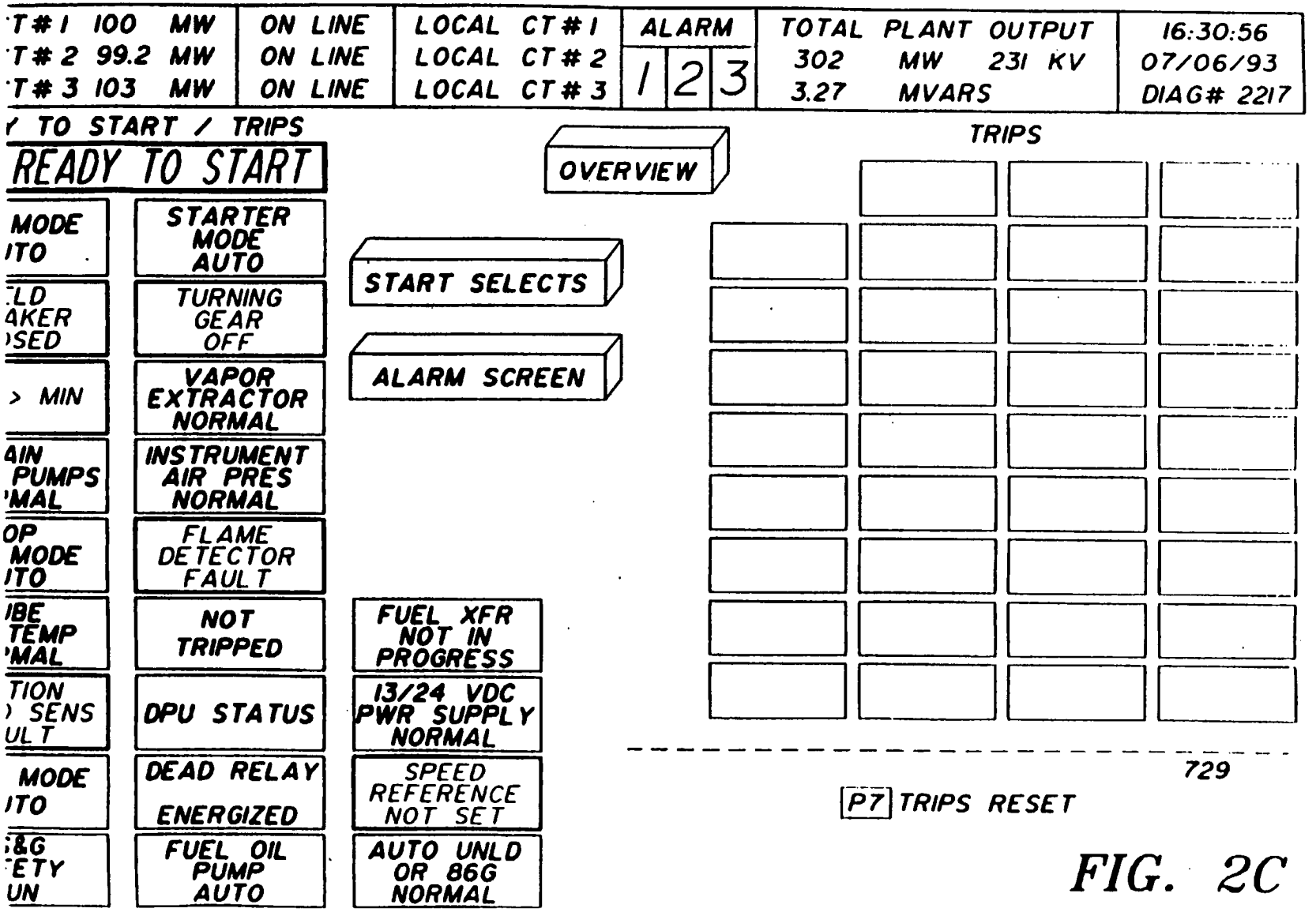
T#1 100 MW
T#2 99.2 MW
T#3 103 MW
ON LINE
ON LINE
ON LINE
LOCAL CT#1
LOCAL CT#2
LOCAL CT#3
ALARM
1 2 3
TOTAL PLANT OUTPUT
302 MW 231 KV
3.27 MVARS
16:30:56
07/06/93
DIAG# 2217
TO START / TRIPS
READY TO START
OVERVIEW
TRIPS
START SELECTS
ALARM SCREEN
MODE ITO
STARTER MODE AUTO
LD AKER SED
TURNING GEAR OFF
> MIN
VAPOR EXTRACTOR NORMAL
AIN PUMPS MAL
INSTRUMENT AIR PRES NORMAL
OP MODE ITO
FLAME DETECTOR FAULT
IBE TEMP MAL
NOT TRIPPED
FUEL XFR NOT IN PROGRESS
TION SENS ULT
DPU STATUS
13/24 VDC PWR SUPPLY NORMAL
MODE ITO
DEAD RELAY ENERGIZED
SPEED REFERENCE NOT SET
&G ETY UN
FUEL OIL PUMP AUTO
AUTO UNLD OR 86G NORMAL
729
P7 TRIPS RESET

FIG. 2C

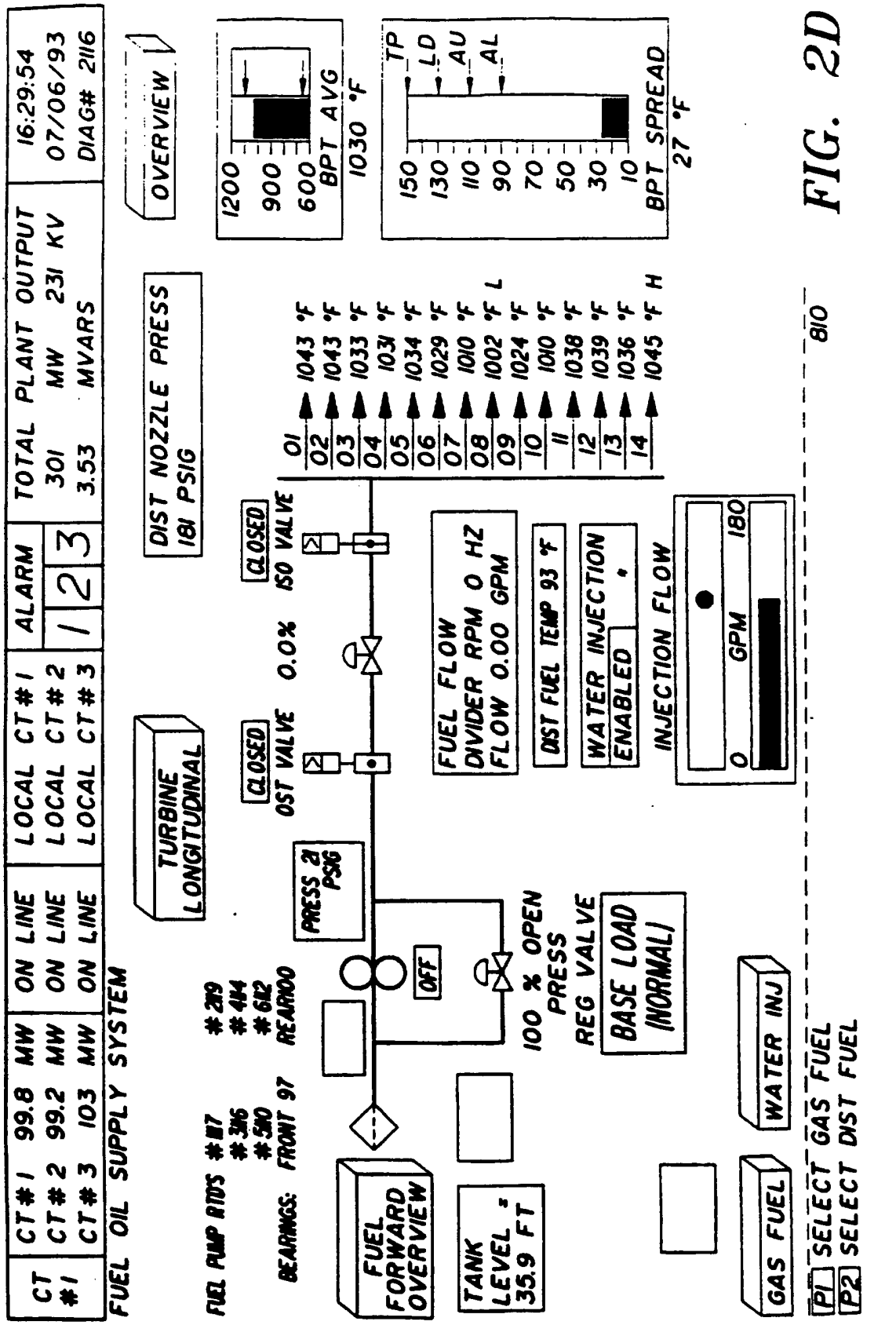
CT #1
CT #1 99.8 MW ON LINE LOCAL CT #1
CT #2 99.2 MW ON LINE LOCAL CT #2
CT #3 103 MW ON LINE LOCAL CT #3
ALARM 1 2 3
TOTAL PLANT OUTPUT
301 MW 231 KV
3.53 MVARS
16:29:54
07/06/93
DIAG# 2116
FUEL OIL SUPPLY SYSTEM
OVERVIEW
DIST NOZZLE PRESS
181 PSIG
1200
900
600
BPT AVG
1030 °F
TP
LD
AU
AL
150
130
110
90
70
50
30
10
BPT SPREAD
27 °F
TURBINE LONGITUDINAL
CLOSED
OST VALVE 0.0%
CLOSED
ISO VALVE
01 1043 °F
02 1043 °F
03 1033 °F
04 1031 °F
05 1034 °F
06 1029 °F
07 1010 °F
08 1002 °F L
09 1024 °F
10 1010 °F
11 1038 °F
12 1039 °F
13 1036 °F
14 1045 °F H
FUEL PUMP RIDS #117 #316 #510 FRONT 97
BEARINGS: #219 #414 #612 REAR100
PRESS 21 PSIG
FUEL FLOW
DIVIDER RPM 0 HZ
FLOW 0.00 GPM
DST FUEL TEMP 93 °F
WATER INJECTION
ENABLED
INJECTION FLOW
GPM
0
180
OFF
100 % OPEN
PRESS
REG VALVE
BASE LOAD
(NORMAL)
FUEL
FORWARD
OVERVIEW
TANK
LEVEL =
35.9 FT
GAS FUEL
WATER INJ
P1 SELECT GAS FUEL
P2 SELECT DST FUEL
810

FIG. 2D

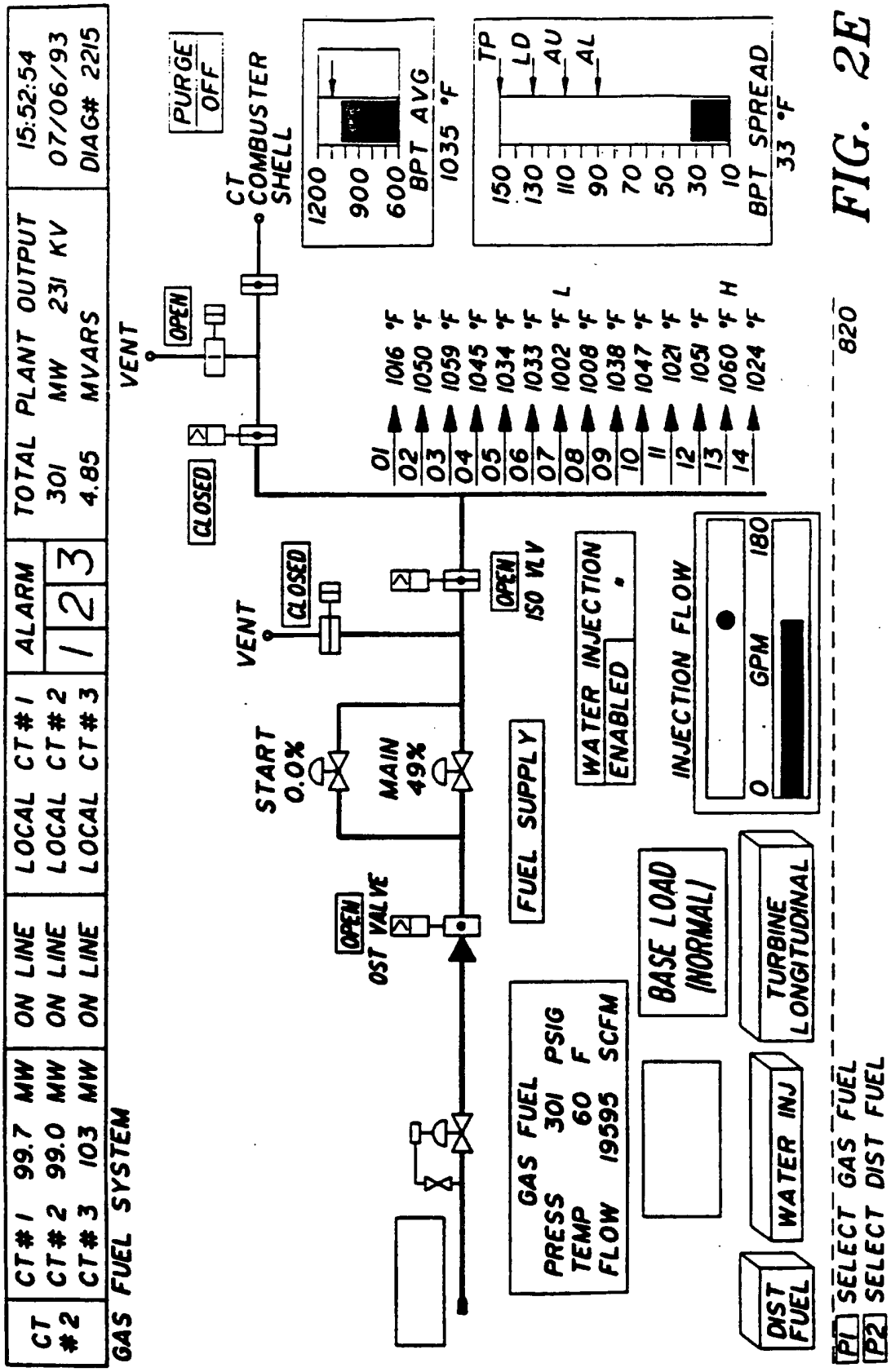
CT #2
CT #1 99.7 MW
CT #2 99.0 MW
CT #3 103 MW
LOCAL CT #1 ON LINE
LOCAL CT #2 ON LINE
LOCAL CT #3 ON LINE
ALARM 1 2 3
TOTAL PLANT OUTPUT
301 MW 231 KV
4.85 MVARS
15:52:54
07/06/93
DIAG# 2215
GAS FUEL SYSTEM
VENT
OPEN
PURGE OFF
CT COMBUSTER SHELL
CLOSED
1200 900 600 BPT AVG
1035 °F
TP LD AU AL
150 130 110 90 70 50 30 10 BPT SPREAD
33 °F
01 106 °F
02 1050 °F
03 1059 °F
04 1045 °F
05 1034 °F
06 1033 °F
07 1002 °F L
08 1008 °F
09 1038 °F
10 1047 °F
11 1021 °F
12 1051 °F
13 1060 °F H
14 1024 °F
820
VENT
CLOSED
OPEN ISO VLV
START 0.0%
MAIN 49%
OPEN OST VALVE
FUEL SUPPLY
WATER INJECTION ENABLED
INJECTION FLOW
0 GPM 180
GAS FUEL
PRESS 301 PSIG
TEMP 60 F
FLOW 19595 SCFM
BASE LOAD (NORMAL)
TURBINE LONGITUDINAL
DIST FUEL
WATER INJ
P1 SELECT GAS FUEL
P2 SELECT DIST FUEL

FIG. 2E

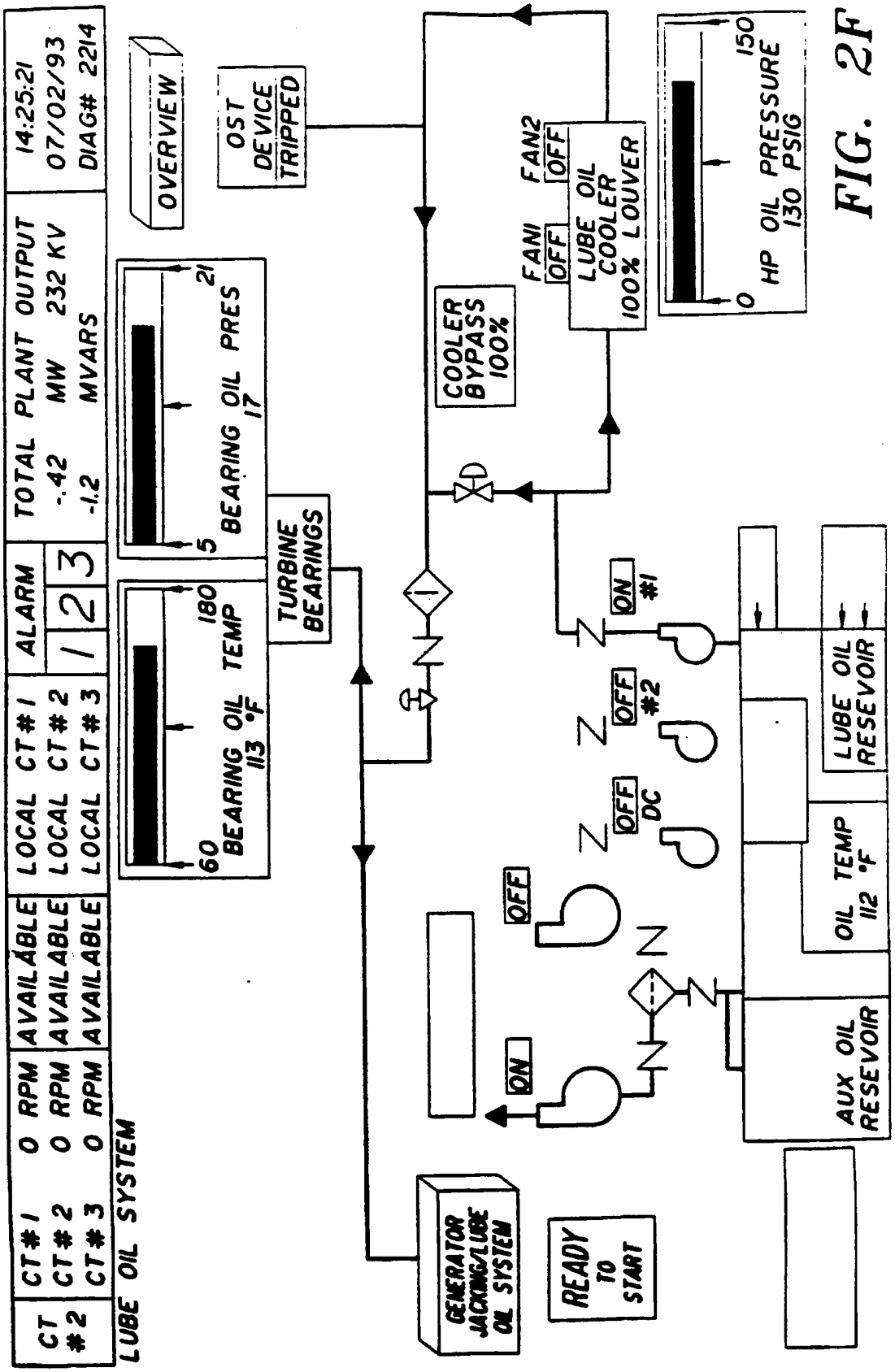
LUBE OIL SYSTEM
CT #2
CT #1 0 RPM AVAILABLE LOCAL CT #1
CT #2 0 RPM AVAILABLE LOCAL CT #2
CT #3 0 RPM AVAILABLE LOCAL CT #3
ALARM 1 2 3
TOTAL PLANT OUTPUT
-.42 MW 232 KV
-1.2 MVARS
14:25:21
07/02/93
DIAG# 2214
OVERVIEW
OST DEVICE TRIPPED
BEARING OIL TEMP 113 °F
60 180
BEARING OIL PRES 17
5 21
TURBINE BEARINGS
COOLER BYPASS 100%
FAN1 OFF
FAN2 OFF
LUBE OIL COOLER 100% LOUVER
HP OIL PRESSURE 130 PSIG
0 150
ON #1
OFF #2
OFF DC
OFF
ON
OIL TEMP 112 °F
LUBE OIL RESEVOIR
AUX OIL RESEVOIR
GENERATOR JACKING/LUBE OIL SYSTEM
READY TO START

FIG. 2F

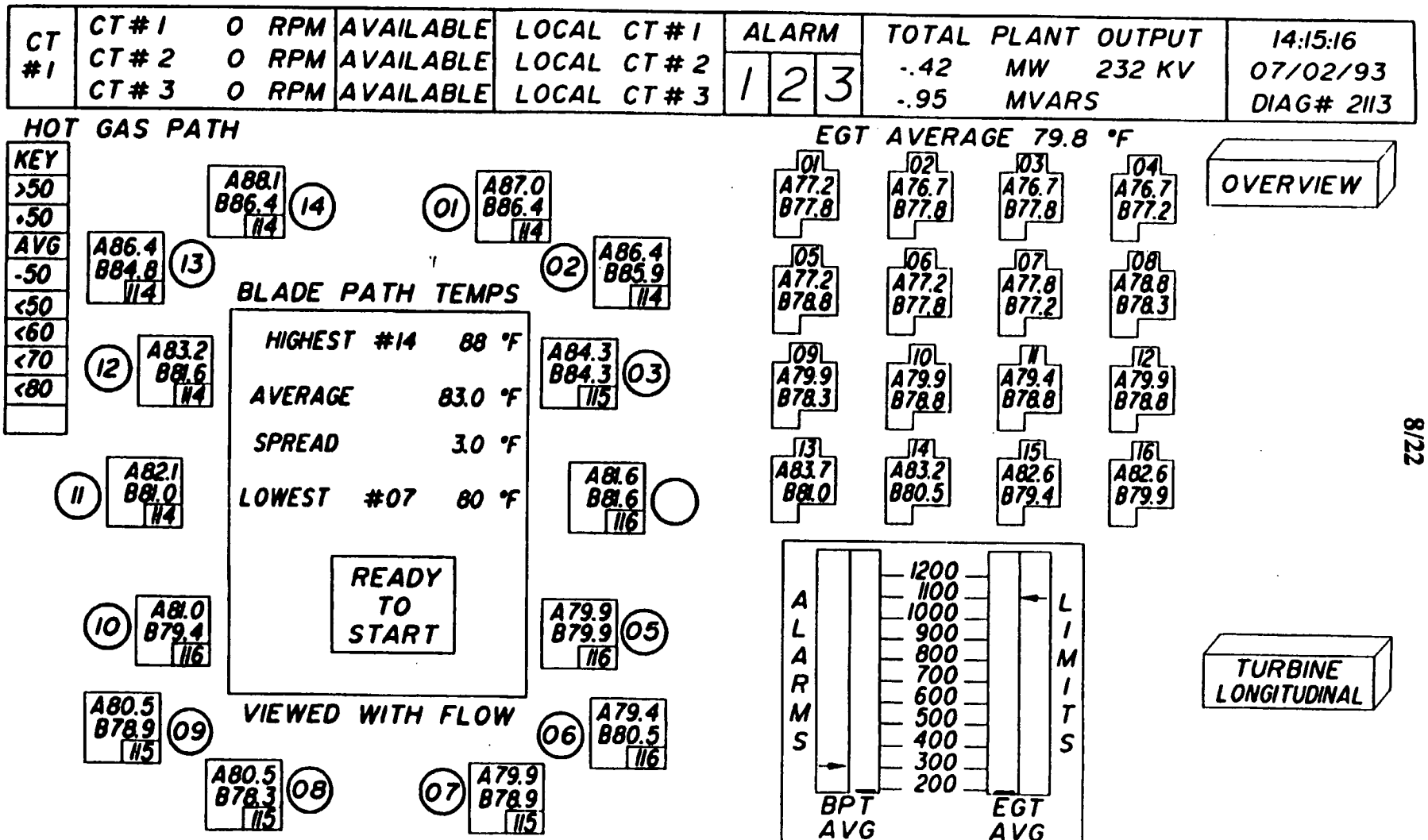

FIG. 2G

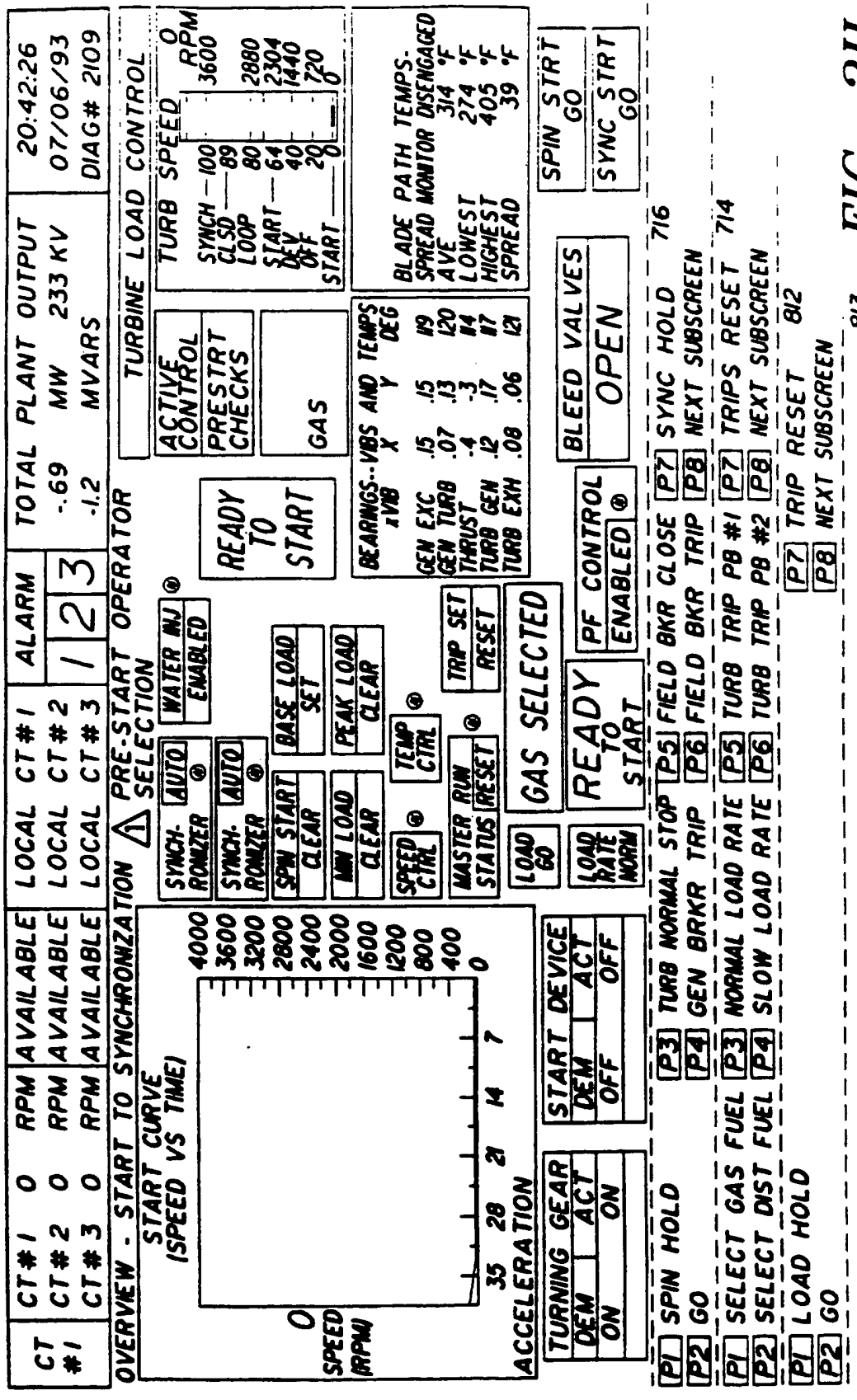
CT #1
CT #1 0 RPM AVAILABLE
CT #2 0 RPM AVAILABLE
CT #3 0 RPM AVAILABLE
LOCAL CT #1
LOCAL CT #2
LOCAL CT #3
ALARM 1 2 3
TOTAL PLANT OUTPUT
-.69 MW 233 KV
.1.2 MVARS
20:42:26
07/06/93
DIAG# 2109
OVERVIEW - START TO SYNCHRONIZATION
PRE-START OPERATOR SELECTION
TURBINE LOAD CONTROL
ACTIVE CONTROL
PRESTRT CHECKS
GAS
TURB SPEED RPM
SYNCH — 100 — 3600
CLSD — 89
LOOP — 80 — 2880
START — 64 — 2304
REV — 40 — 1440
OFF — 20 — 720
START — 0 — 0
BLADE PATH TEMPS-
SPREAD MONITOR DISENGAGED
AVE 314 °F
LOWEST 274 °F
HIGHEST 405 °F
SPREAD 39 °F
BEARINGS-- VIBS AND TEMPS
1VIB X Y DEG
GEN EXC .15 .15 119
GEN TURB .07 .13 120
THRUST .4 -.3 114
TURB GEN .12 .17 117
TURB EXH .08 .06 121
READY TO START
SYNCH-RONIZER AUTO
WATER INJ ENABLED
SPD START CLEAR
BASE LOAD SET
MW LOAD CLEAR
PEAK LOAD CLEAR
SPEED CTRL
TEMP CTRL
MASTER RUN STATUS RESET
TRIP SET RESET
LOAD GO
GAS SELECTED
LOAD RATE NORM
READY TO START
PF CONTROL ENABLED
BLEED VALVES
OPEN
SPIN STRT GO
SYNC STRT GO
START CURVE (SPEED VS TIME)
SPEED (RPM)
ACCELERATION
TURNING GEAR
DEM ACT
ON ON
START DEVICE
DEM ACT
OFF OFF
P1 SPIN HOLD
P2 GO
P3 TURB NORMAL STOP
P4 GEN BRKR TRIP
P5 FIELD BKR CLOSE
P6 FIELD BKR TRIP
P7 SYNC HOLD
P8 NEXT SUBSCREEN
716
P1 SELECT GAS FUEL
P2 SELECT DST FUEL
P1 LOAD HOLD
P2 GO
P3 NORMAL LOAD RATE
P4 SLOW LOAD RATE
P5 TURB TRIP PB #1
P6 TURB TRIP PB #2
P7 TRIPS RESET
P8 NEXT SUBSCREEN
714
P7 TRIP RESET
P8 NEXT SUBSCREEN
812
813
P4 CONSOLE ENABLED
P8 NEXT SUBSCREEN

FIG. 2H

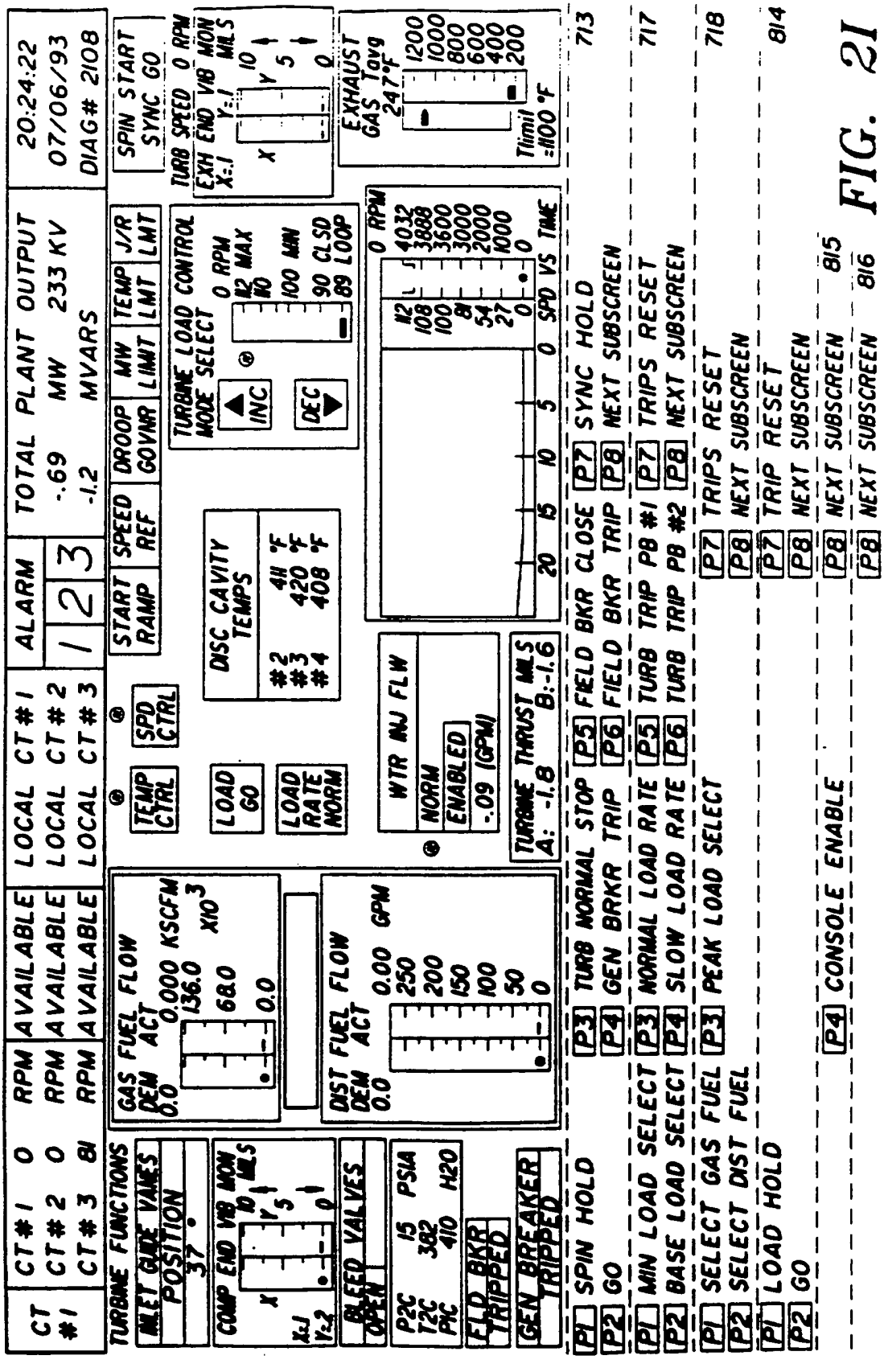
CT #1
CT #1 0 RPM
CT #2 0 RPM
CT #3 81 RPM
AVAILABLE
AVAILABLE
AVAILABLE
LOCAL CT #1
LOCAL CT #2
LOCAL CT #3
ALARM
1 2 3
TOTAL PLANT OUTPUT
-.69 MW 233 KV
-1.2 MVARS
20:24:22
07/06/93
DIAG# 2108
START RAMP
SPEED REF
DROOP GOVNR
MW LIMIT
TEMP LMT
J/R LMT
SPIN START
SYNC GO
TURBINE FUNCTIONS
INLET GUIDE VANES POSITION 37°
COMP END VIB MON 0 5 10 MILS
X:1
Y:2
BLEED VALVES OPEN
P2C 15 PSIA
T2C 382
PIC 410 H20
FLD BKR TRIPPED
GEN BREAKER TRIPPED
TEMP CTRL
SPD CTRL
LOAD GO
LOAD RATE NORM
GAS FUEL FLOW DEM 0.0 ACT 0.000 KSCFM
136.0
68.0
0.0
X10^3
DIST FUEL FLOW DEM 0.0 ACT 0.00 GPM
250
200
150
100
50
0
DISC CAVITY TEMPS
#2 411 °F
#3 420 °F
#4 408 °F
WTR INJ FLW
NORM
ENABLED
-.09 (GPM)
TURBINE THRUST MILS A: -1.8 B:-1.6
TURBINE LOAD CONTROL MODE SELECT
INC
DEC
0 RPM
112 MAX
110 MIN
90 CLSD
89 LOOP
0 RPM
4032
3888
3600
3000
2000
1000
0
112
108
100
81
54
27
0
20 15 10 5 0 SPD VS TIME
TURB SPEED 0 RPM
EXH END VIB MON MILS
X:1 Y:1
X
Y
10
5
0
EXHAUST GAS Tavg 247°F
1200
1000
800
600
400
200
Tlimit =1100 °F
P1 SPIN HOLD
P2 GO
P3 TURB NORMAL STOP
P4 GEN BRKR TRIP
P5 FIELD BKR CLOSE
P6 FIELD BKR TRIP
P7 SYNC HOLD
P8 NEXT SUBSCREEN
713
P1 MIN LOAD SELECT
P2 BASE LOAD SELECT
P3 NORMAL LOAD RATE
P4 SLOW LOAD RATE
P5 TURB TRIP PB #1
P6 TURB TRIP PB #2
P7 TRIPS RESET
P8 NEXT SUBSCREEN
717
P1 SELECT GAS FUEL
P2 SELECT DST FUEL
P3 PEAK LOAD SELECT
P7 TRIPS RESET
P8 NEXT SUBSCREEN
718
P1 LOAD HOLD
P2 GO
P4 CONSOLE ENABLE
P7 TRIP RESET
P8 NEXT SUBSCREEN
814
P8 NEXT SUBSCREEN
815
P8 NEXT SUBSCREEN
816

FIG. 21

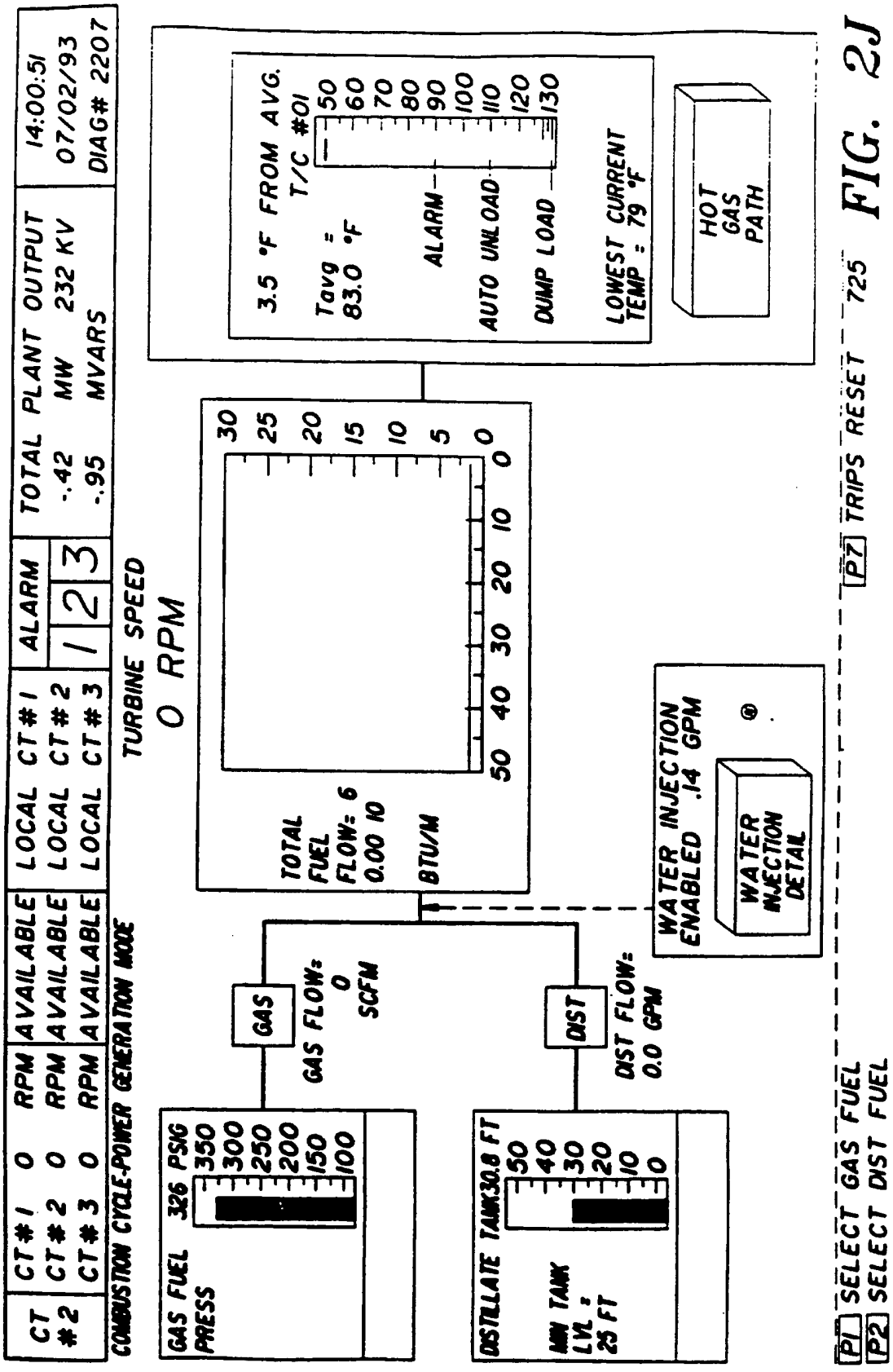
CT #2
CT #1 0 RPM AVAILABLE LOCAL CT #1
CT #2 0 RPM AVAILABLE LOCAL CT #2
CT #3 0 RPM AVAILABLE LOCAL CT #3
ALARM 1 2 3
TOTAL PLANT OUTPUT
.42 MW 232 KV
.95 MVARS
14:00:51
07/02/93
DIAG# 2207
COMBUSTION CYCLE-POWER GENERATION MODE
TURBINE SPEED
0 RPM
3.5 °F FROM AVG. T/C #01
Tavg = 83.0 °F
ALARM
AUTO UNLOAD
DUMP LOAD
LOWEST CURRENT TEMP = 79 °F
HOT GAS PATH
TOTAL FUEL FLOW= 6 0.00 10
BTU/M
WATER INJECTION ENABLED .14 GPM
WATER INJECTION DETAIL
GAS FUEL PRESS 326 PSIG
GAS
GAS FLOW= 0 SCFM
DISTILLATE TANK 30.8 FT
DST
DST FLOW= 0.0 GPM
MN TANK LVL = 25 FT
P1 SELECT GAS FUEL
P2 SELECT DST FUEL
P7 TRIPS RESET 725

FIG. 2J

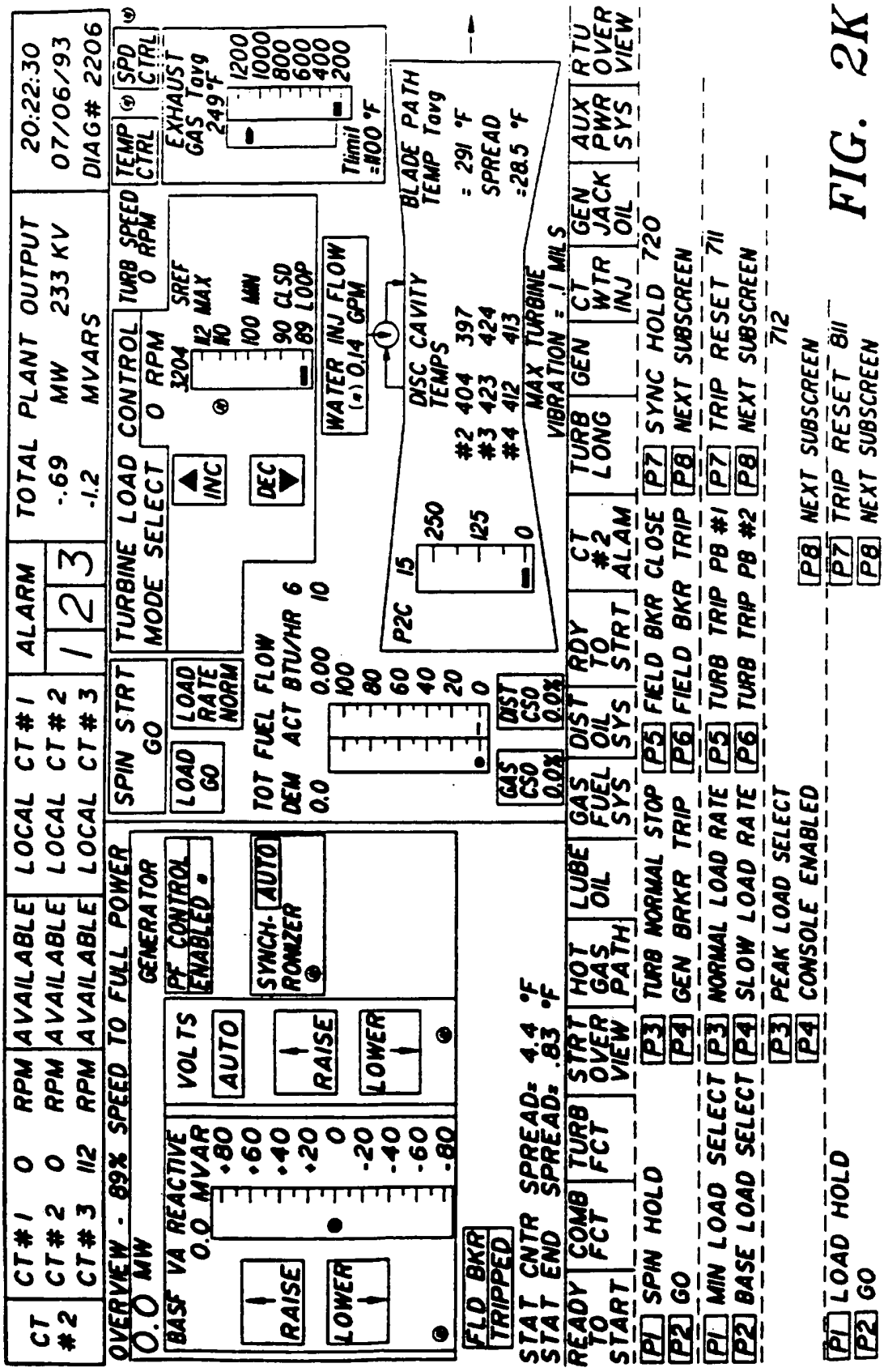
CT #2
CT #1 0 RPM AVAILABLE
CT #2 0 RPM AVAILABLE
CT #3 112 RPM AVAILABLE
LOCAL CT #1
LOCAL CT #2
LOCAL CT #3
ALARM 1 2 3
TOTAL PLANT OUTPUT
-.69 MW 233 KV
-1.2 MVARS
20:22:30
07/06/93
DIAG# 2206
OVERVIEW - 89% SPEED TO FULL POWER
0.0 MW
GENERATOR
BASE VA REACTIVE 0.0 MVAR
.80 .60 .40 .20 0 -.20 -.40 -.60 -.80
RAISE
LOWER
VOLTS
AUTO
RAISE
LOWER
PF CONTROL ENABLED
SYNCH-RONIZER AUTO
SPIN STRT GO
LOAD GO
LOAD RATE NORM
TURBINE LOAD CONTROL
MODE SELECT
INC
DEC
TOT FUEL FLOW
DEM ACT BTU/HR 6
0.0 0.00 10
100 80 60 40 20 0
GAS CSO 0.0%
DIST CSO 0.0%
TURB SPEED 0 RPM
0 RPM
3204
SREF
112 MAX
110 MIN
100 MIN
90 CLSD
89 LOOP
WATER INJ FLOW
(-) 0.14 GPM
P2C 15 250 125 0
DISC CAVITY TEMPS
#2 404 397
#3 423 424
#4 412 413
MAX TURBINE VIBRATION = .1 MILS
BLADE PATH TEMP Tavg
= 291 °F
SPREAD
=28.5 °F
TEMP CTRL
SPD CTRL
EXHAUST GAS Tavg 249°F
1200 1000 800 600 400 200
Timil =100 °F
FLD BKR TRIPPED
STAT CNTR SPREAD= 4.4 °F
STAT END SPREAD= .83 °F
READY TO START
COMB FCT
TURB FCT
START OVER VIEW
HOT GAS PATH
LUBE OIL
GAS FUEL SYS
DIST OIL SYS
RDY TO STRT
CT #2 ALAM
TURB LONG
GEN
CT WTR INJ
GEN JACK OIL
AUX PWR SYS
RTU OVER VIEW
P1 SPIN HOLD
P2 GO
P3 TURB NORMAL STOP
P4 GEN BRKR TRIP
P5 FIELD BKR CLOSE
P6 FIELD BKR TRIP
P7 SYNC HOLD 720
P8 NEXT SUBSCREEN
P1 MIN LOAD SELECT
P2 BASE LOAD SELECT
P3 NORMAL LOAD RATE
P4 SLOW LOAD RATE
P5 TURB TRIP PB #1
P6 TURB TRIP PB #2
P7 TRIP RESET 711
P8 NEXT SUBSCREEN
712
P3 PEAK LOAD SELECT
P4 CONSOLE ENABLED
P8 NEXT SUBSCREEN
P1 LOAD HOLD
P2 GO
P7 TRIP RESET 811
P8 NEXT SUBSCREEN

FIG. 2K

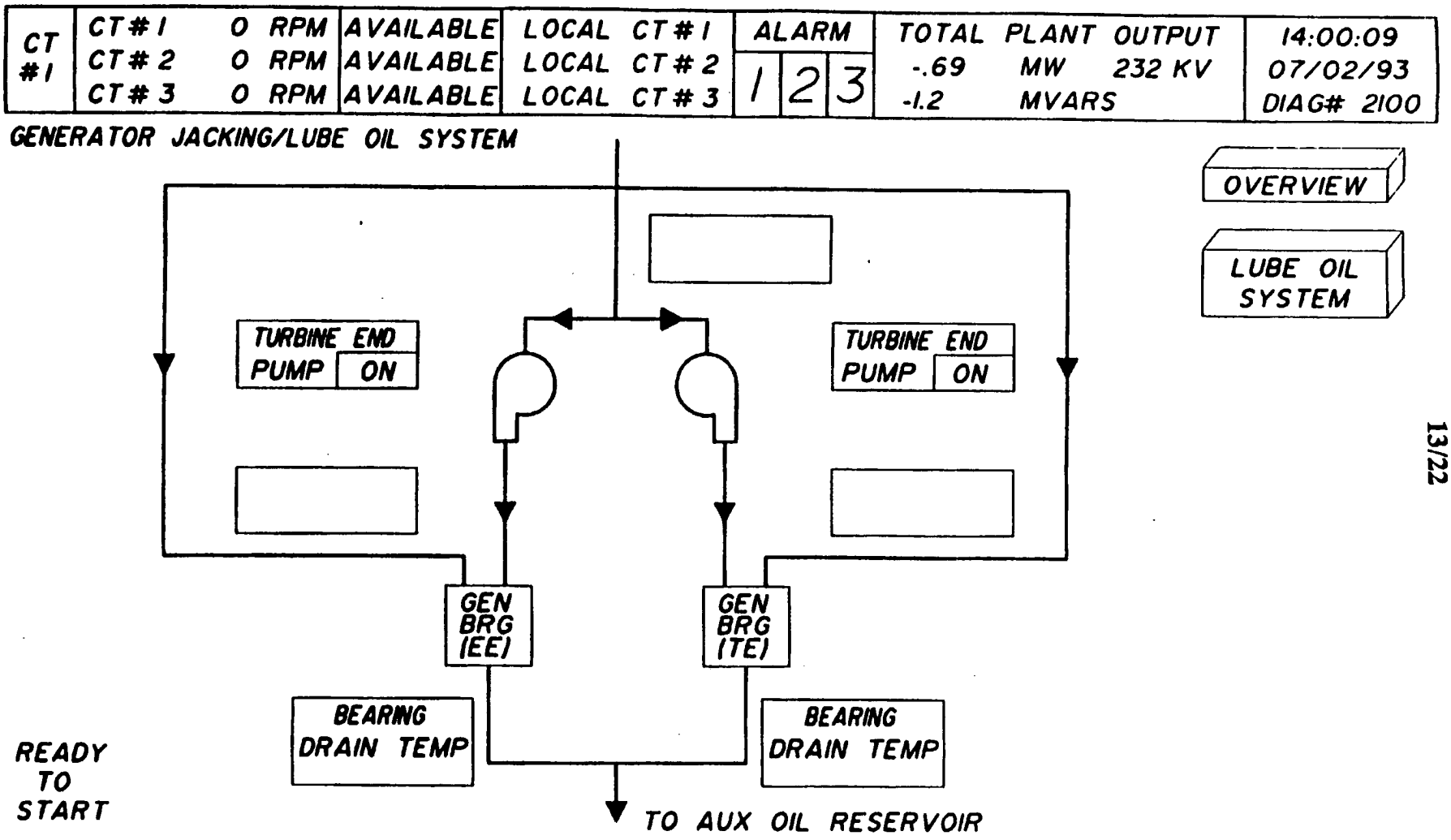
CT #1
CT#1 0 RPM
CT#2 0 RPM
CT#3 0 RPM
AVAILABLE
AVAILABLE
AVAILABLE
LOCAL CT#1
LOCAL CT#2
LOCAL CT#3
ALARM
1 2 3
TOTAL PLANT OUTPUT
-.69 MW 232 KV
-1.2 MVARS
14:00:09
07/02/93
DIAG# 2100
GENERATOR JACKING/LUBE OIL SYSTEM
OVERVIEW
LUBE OIL SYSTEM
TURBINE END PUMP ON
TURBINE END PUMP ON
GEN BRG (EE)
GEN BRG (TE)
BEARING DRAIN TEMP
BEARING DRAIN TEMP
READY TO START
TO AUX OIL RESERVOIR

FIG. 2L

BOP	CT#1 0 RPM CT#2 0 RPM CT#3 0 RPM	AVAILABLE AVAILABLE AVAILABLE	LOCAL CT#1 LOCAL CT#2 LOCAL CT#3	ALARM 1 2 3	TOTAL PLANT OUTPUT -.42 MW 232 KV -.95 MVARS		13:48:10 07/06/93 DIAG #2022

BOP PROTECTIVE RELAY ALARMS

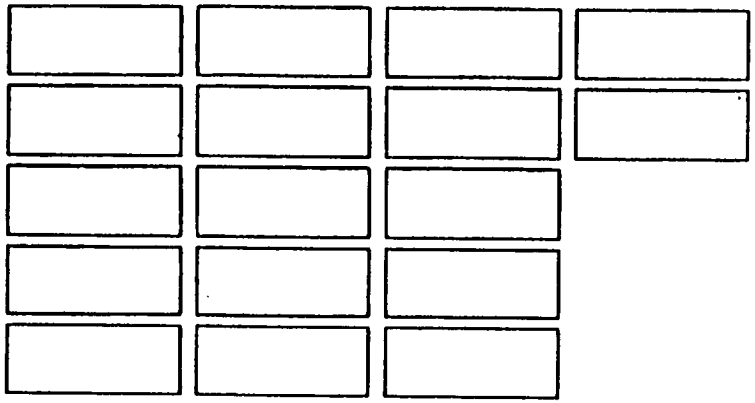

FIG. 2M

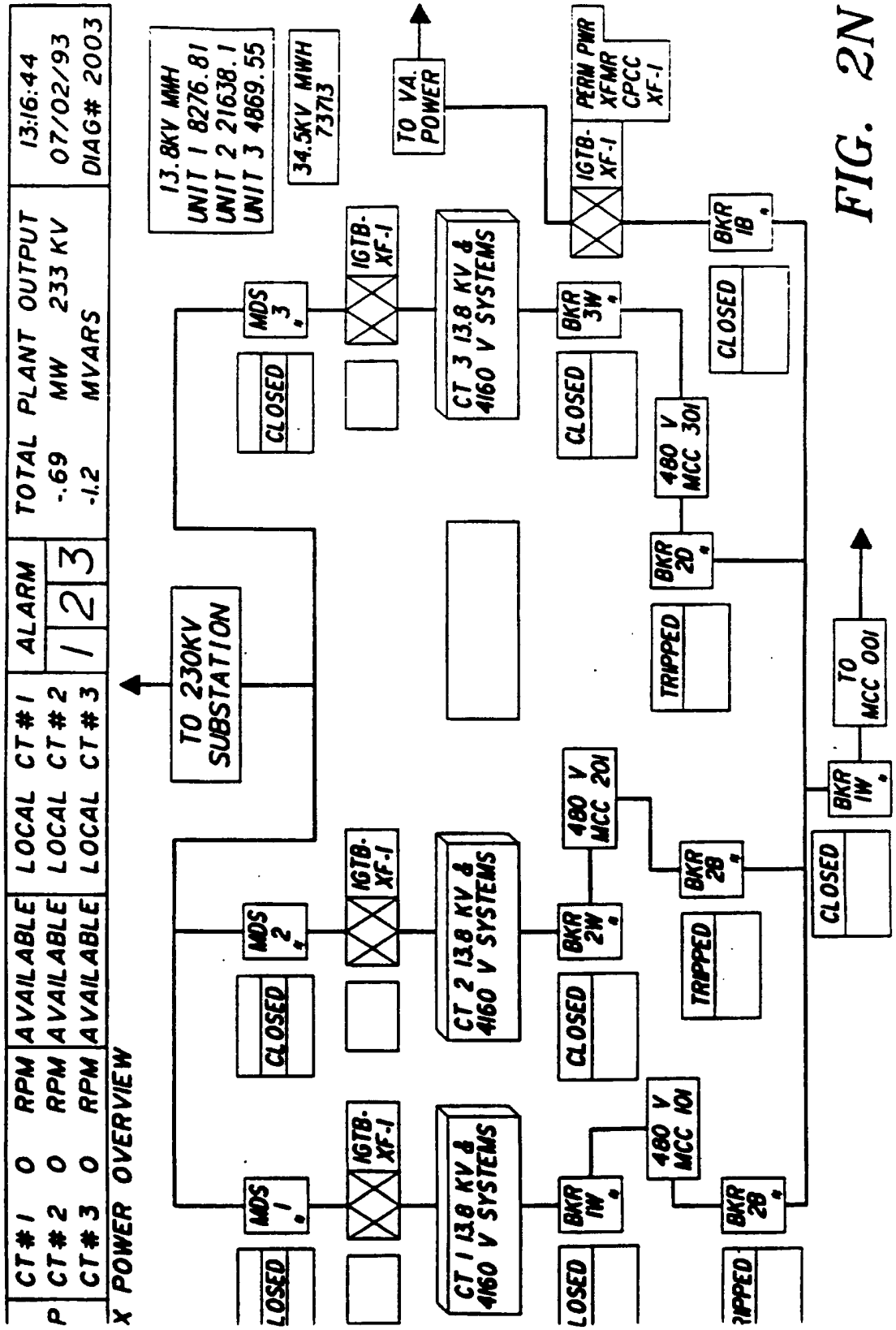
POWER OVERVIEW
CT#1 0 RPM AVAILABLE LOCAL CT#1
CT#2 0 RPM AVAILABLE LOCAL CT#2
CT#3 0 RPM AVAILABLE LOCAL CT#3
ALARM 1 2 3
TOTAL PLANT OUTPUT
-.69 MW 233 KV
-1.2 MVARS
13:16:44
07/02/93
DIAG# 2003
13.8KV MWH
UNIT 1 8276.81
UNIT 2 21638.1
UNIT 3 4869.55
34.5KV MWH
73713
TO 230KV SUBSTATION
TO VA. POWER
MDS 1
MDS 2
MDS 3
IGTB-XF-1
CT 1 13.8 KV & 4160 V SYSTEMS
CT 2 13.8 KV & 4160 V SYSTEMS
CT 3 13.8 KV & 4160 V SYSTEMS
BKR 1W
BKR 2W
BKR 3W
BKR 1B
BKR 2B
BKR 2D
480 V MCC 10I
480 V MCC 20I
480 V MCC 30I
PERM PWR XFMR CPCC XF-1
TO MCC 001
CLOSED
TRIPPED

FIG. 2N

BOP	CT#1 0 RPM	AVAILABLE	LOCAL CT#1	ALARM			TOTAL PLANT OUTPUT	13:18:16
	CT#2 0 RPM	AVAILABLE	LOCAL CT#2	1	2	3	-.42 MW 233 KV	07/02/93
	CT#3 0 RPM	AVAILABLE	LOCAL CT#3				-.69 MVARS	DIAG# 2004

TRANSFORMER ALARMS

1GTB-XF-1 ALARMS

2GTB-XF-2 ALARMS

3GTB-XF-3 ALARMS

1APA-XF-1B ALARMS

2APA-XF-2B ALARMS

3APA-XF-3B ALARMS

1APA-XF-1A ALARMS

2APA-XF-2A ALARMS

3APA-XF-3A ALARMS

FIG. 20

WO 96/07958
US95/10998

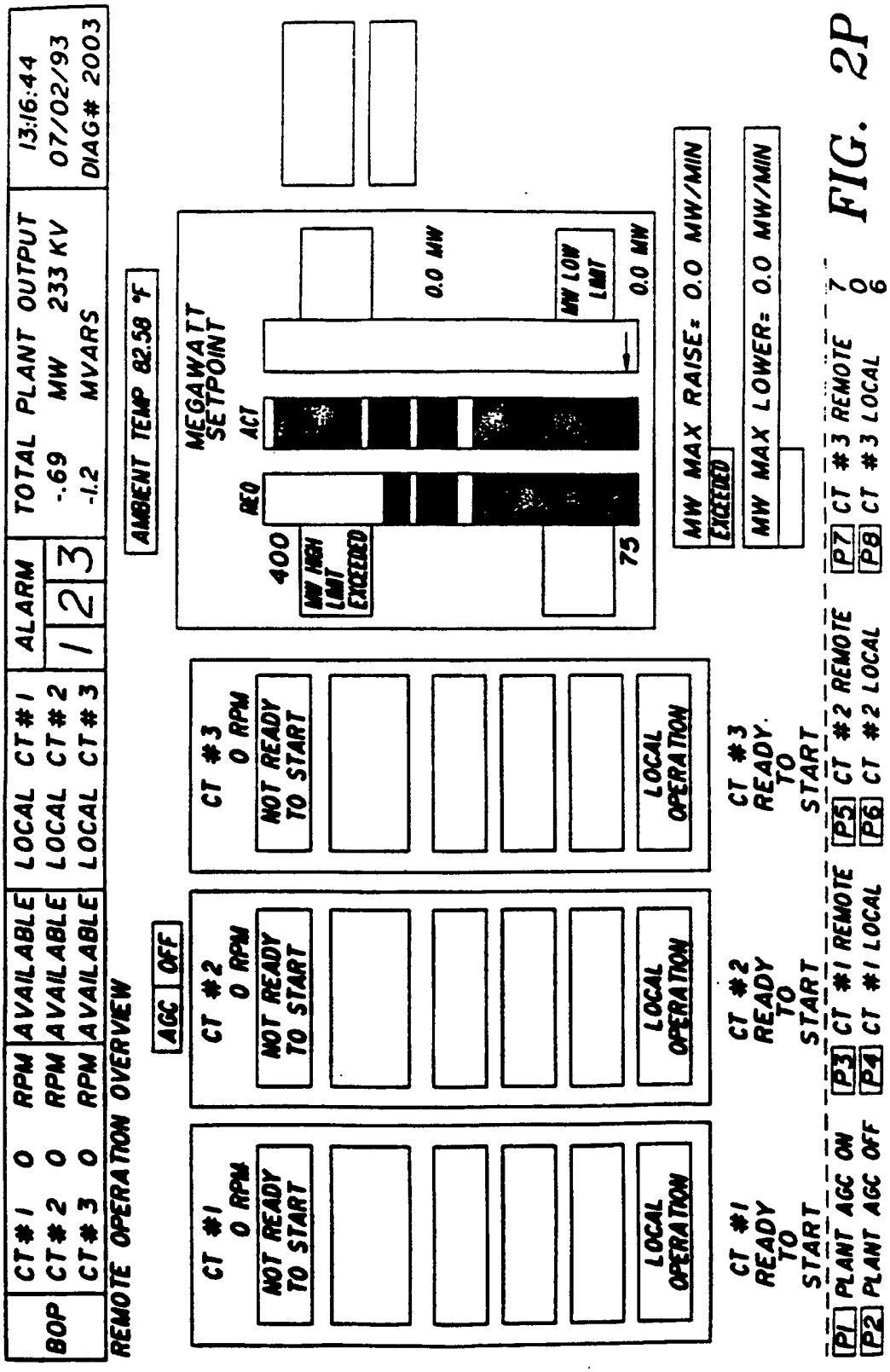
BOP
CT#1 0 RPM AVAILABLE
CT#2 0 RPM AVAILABLE
CT#3 0 RPM AVAILABLE
LOCAL CT#1
LOCAL CT#2
LOCAL CT#3
ALARM
1 2 3
TOTAL PLANT OUTPUT
-.69 MW 233 KV
-1.2 MVARS
13:16:44
07/02/93
DIAG# 2003
REMOTE OPERATION OVERVIEW
AMBIENT TEMP 82.58 °F
AGC OFF
CT #1 0 RPM
NOT READY TO START
LOCAL OPERATION
CT #2 0 RPM
NOT READY TO START
LOCAL OPERATION
CT #3 0 RPM
NOT READY TO START
LOCAL OPERATION
CT #1 READY TO START
CT #2 READY TO START
CT #3 READY TO START
MEGAWATT SETPOINT
REQ
ACT
400
75
MW HIGH LIMIT EXCEEDED
0.0 MW
MW LOW LIMIT
0.0 MW
MW MAX RAISE= 0.0 MW/MIN
EXCEEDED
MW MAX LOWER= 0.0 MW/MIN
P1 PLANT AGC ON
P2 PLANT AGC OFF
P3 CT #1 REMOTE
P4 CT #1 LOCAL
P5 CT #2 REMOTE
P6 CT #2 LOCAL
P7 CT #3 REMOTE 7
P8 CT #3 LOCAL 6

FIG. 2P

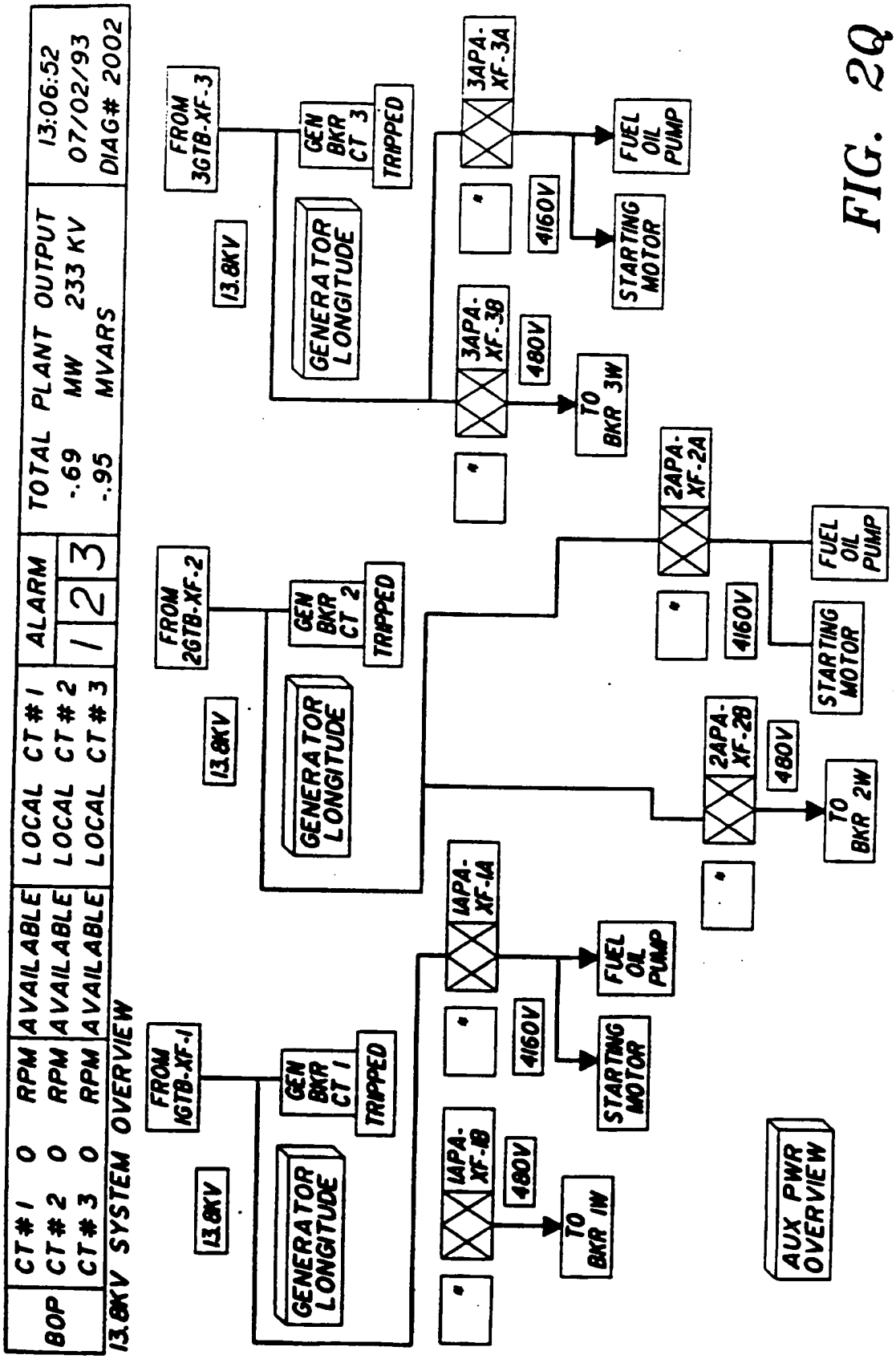
BOP
CT#1 0 RPM AVAILABLE
CT#2 0 RPM AVAILABLE
CT#3 0 RPM AVAILABLE
13.8KV SYSTEM OVERVIEW
LOCAL CT#1
LOCAL CT#2
LOCAL CT#3
ALARM
1 2 3
TOTAL PLANT OUTPUT
-.69 MW 233 KV
-.95 MVARS
13:06:52
07/02/93
DIAG# 2002
FROM 1GTB-XF-1
13.8KV
GENERATOR LONGITUDE
GEN BKR CT 1
TRIPPED
1APA-XF-1A
1APA-XF-1B
480V
4160V
TO BKR 1W
STARTING MOTOR
FUEL OIL PUMP
FROM 2GTB-XF-2
13.8KV
GENERATOR LONGITUDE
GEN BKR CT 2
TRIPPED
2APA-XF-2A
2APA-XF-2B
480V
4160V
TO BKR 2W
STARTING MOTOR
FUEL OIL PUMP
FROM 3GTB-XF-3
13.8KV
GENERATOR LONGITUDE
GEN BKR CT 3
TRIPPED
3APA-XF-3A
3APA-XF-3B
480V
4160V
TO BKR 3W
STARTING MOTOR
FUEL OIL PUMP
AUX PWR OVERVIEW

FIG. 2Q

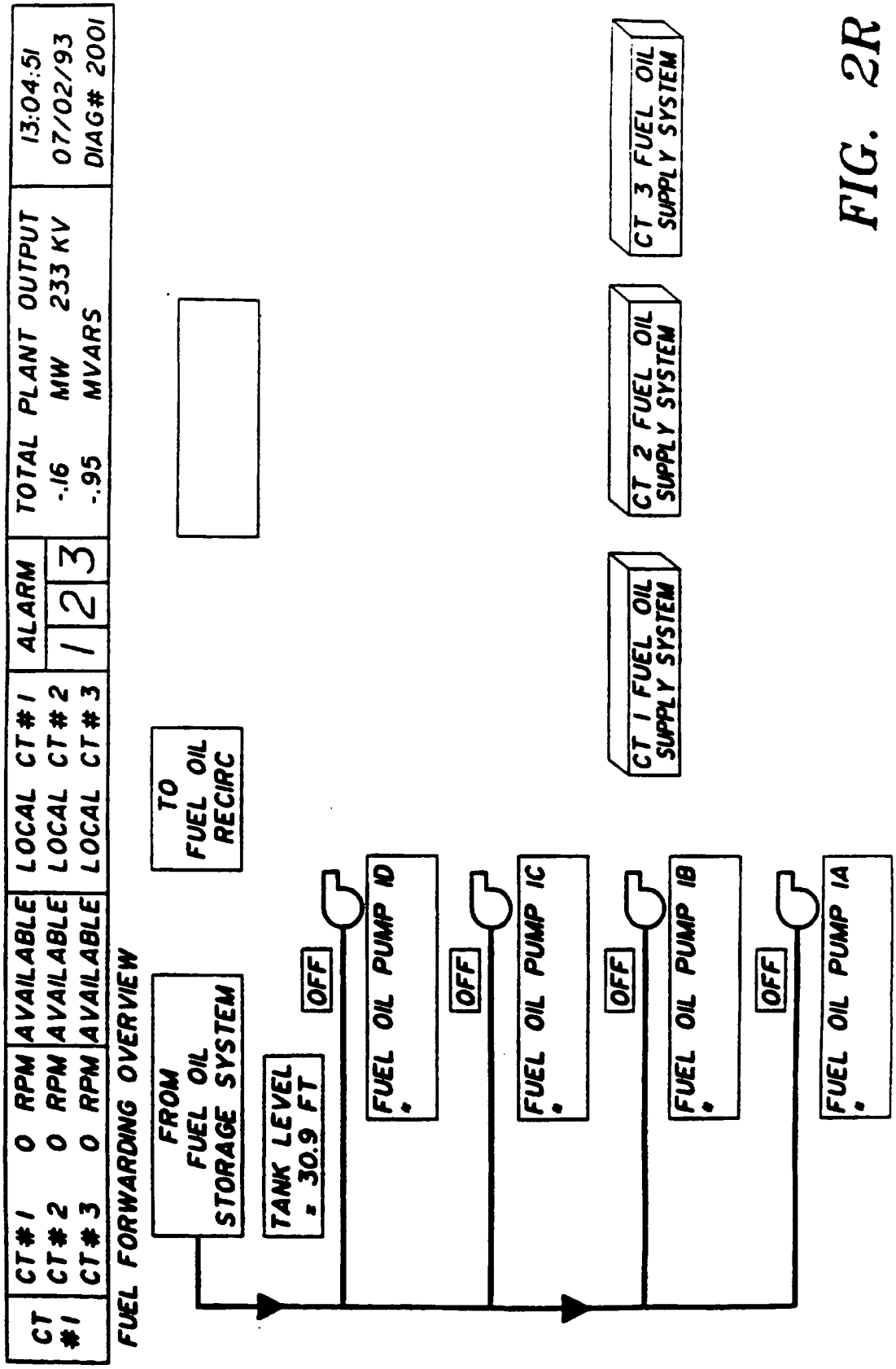
CT #1
CT #1 0 RPM AVAILABLE LOCAL CT #1
CT #2 0 RPM AVAILABLE LOCAL CT #2
CT #3 0 RPM AVAILABLE LOCAL CT #3
ALARM 1 2 3
TOTAL PLANT OUTPUT
-.16 MW 233 KV
-.95 MVARS
13:04:51
07/02/93
DIAG# 2001
FUEL FORWARDING OVERVIEW
FROM FUEL OIL STORAGE SYSTEM
TANK LEVEL = 30.9 FT
TO FUEL OIL RECIRC
OFF
FUEL OIL PUMP 1D
OFF
FUEL OIL PUMP 1C
OFF
FUEL OIL PUMP 1B
OFF
FUEL OIL PUMP 1A
CT 1 FUEL OIL SUPPLY SYSTEM
CT 2 FUEL OIL SUPPLY SYSTEM
CT 3 FUEL OIL SUPPLY SYSTEM

FIG. 2R

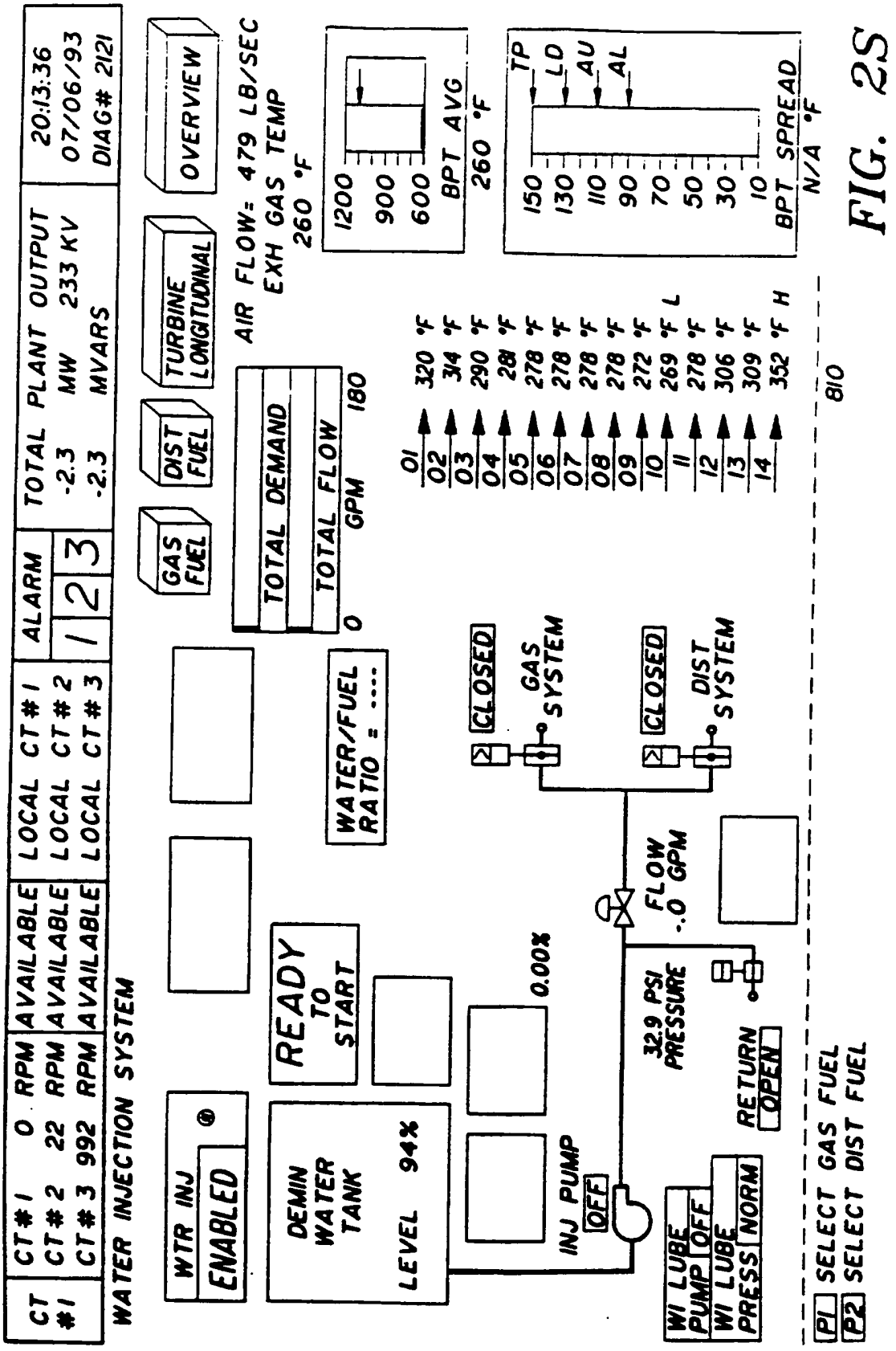
CT #1
CT #1 0 RPM AVAILABLE LOCAL CT # 1
CT # 2 22 RPM AVAILABLE LOCAL CT # 2
CT # 3 992 RPM AVAILABLE LOCAL CT # 3
ALARM 1 2 3
TOTAL PLANT OUTPUT
-2.3 MW 233 KV
-2.3 MVARS
20:13:36
07/06/93
DIAG# 2121
WATER INJECTION SYSTEM
WTR INJ ENABLED
DEMIN WATER TANK
LEVEL 94%
READY TO START
0.00%
INJ PUMP OFF
WI LUBE PUMP OFF
WI LUBE PRESS NORM
32.9 PSI PRESSURE
FLOW .0 GPM
RETURN OPEN
WATER/FUEL RATIO = ...
GAS FUEL
DIST FUEL
TURBINE LONGITUDINAL
OVERVIEW
TOTAL DEMAND
TOTAL FLOW
0 GPM 180
AIR FLOW= 479 LB/SEC
EXH GAS TEMP
260 °F
1200
900
600
BPT AVG
260 °F
TP
LD
AU
AL
150
130
110
90
70
50
30
10
BPT SPREAD
N/A °F
01 320 °F
02 34 °F
03 290 °F
04 281 °F
05 278 °F
06 278 °F
07 278 °F
08 278 °F
09 272 °F
10 269 °F L
11 278 °F
12 306 °F
13 309 °F
14 352 °F H
810
CLOSED
GAS SYSTEM
CLOSED
DIST SYSTEM
P1 SELECT GAS FUEL
P2 SELECT DIST FUEL

FIG. 2S

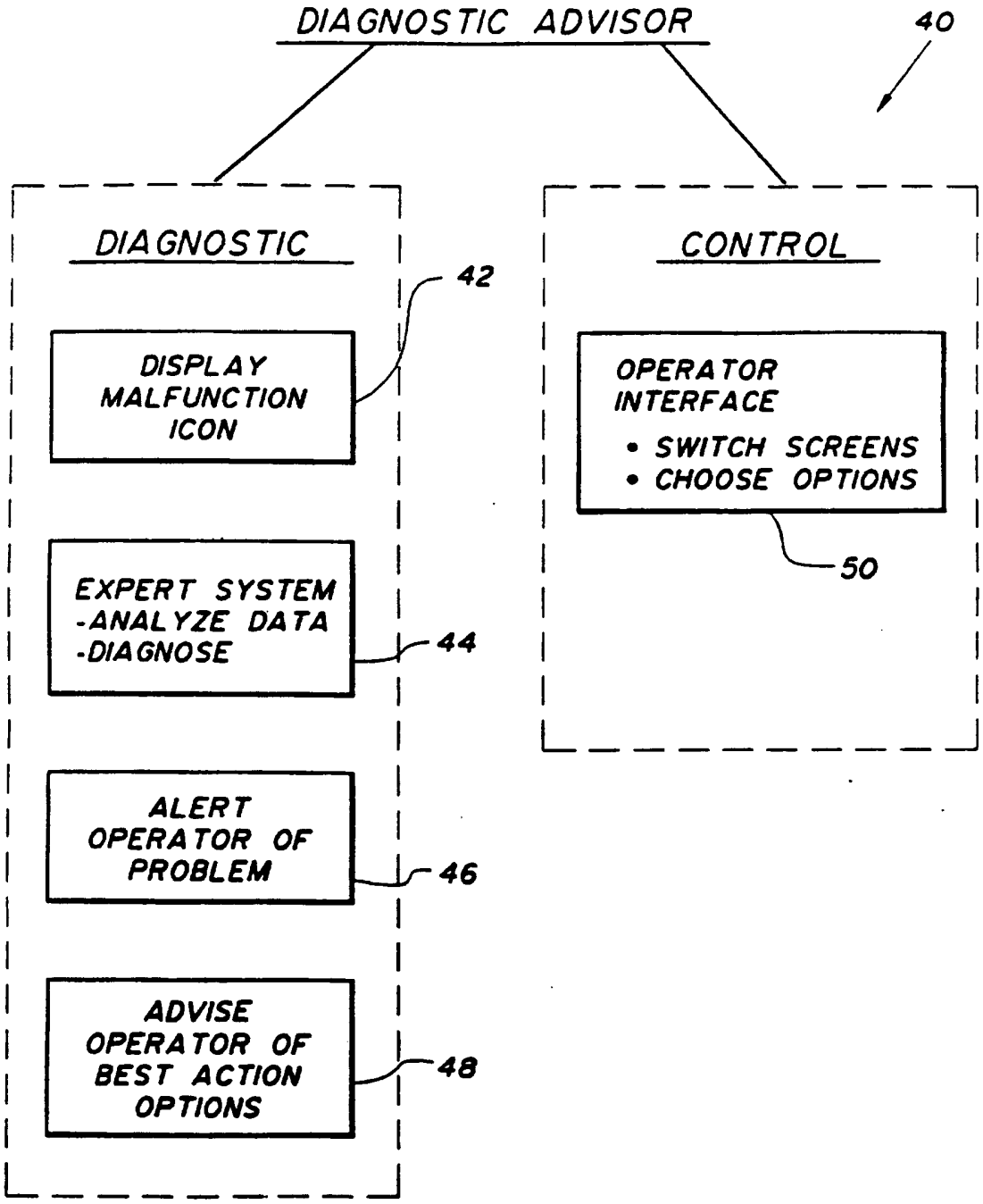
DIAGNOSTIC ADVISOR
40
DIAGNOSTIC
CONTROL
42
DISPLAY MALFUNCTION ICON
OPERATOR INTERFACE
• SWITCH SCREENS
• CHOOSE OPTIONS
50
EXPERT SYSTEM
-ANALYZE DATA
-DIAGNOSE
44
ALERT OPERATOR OF PROBLEM
46
ADVISE OPERATOR OF BEST ACTION OPTIONS
48

FIG. 3

INTERNATIONAL SEARCH REPORT

Inte[illegible]cation No
PCT/US [illegible]5/10998

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 G05B19/418

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 G05B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 528 396 (IBM) 24 February 1993 see page 3, line 34 - page 5, line 43; figures 1,4,5	1-3, 8-11, 14-17
A	---	4-7,12, 13,18,19
A	TECHNISCHE RUNDSCHAU, vol. 80, no. 11, 11 March 1988 pages 58-63, 65, XP 000022343 KIRATLI G. 'EXPERTENSYSTEME FÜR DIE FERTIGUNGSTECHNIK' see page 61, middle column, last paragraph - page 63, right column, paragraph 1; figures 2,3	1-19

	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

1

Date of the actual completion of the international search	Date of mailing of the international search report
19 January 1996	02.02.96
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	**Authorized officer** Nettesheim, J

Form PCT/ISA/210 (second sheet) (July 1992)

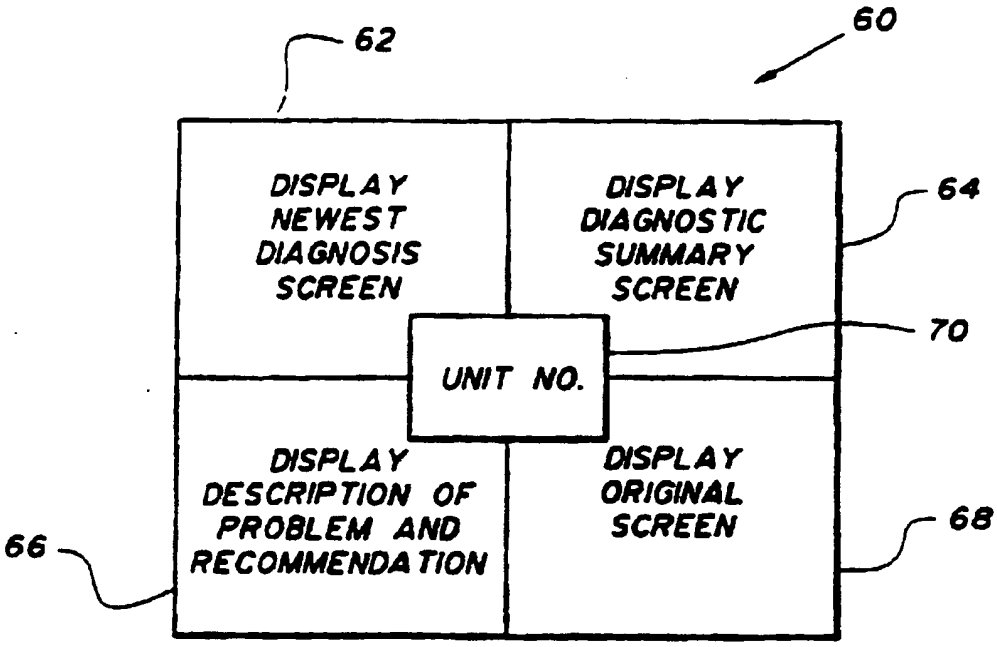
62
60
DISPLAY NEWEST DIAGNOSIS SCREEN
DISPLAY DIAGNOSTIC SUMMARY SCREEN
64
70
UNIT NO.
DISPLAY DESCRIPTION OF PROBLEM AND RECOMMENDATION
DISPLAY ORIGINAL SCREEN
66
68

FIG. 4

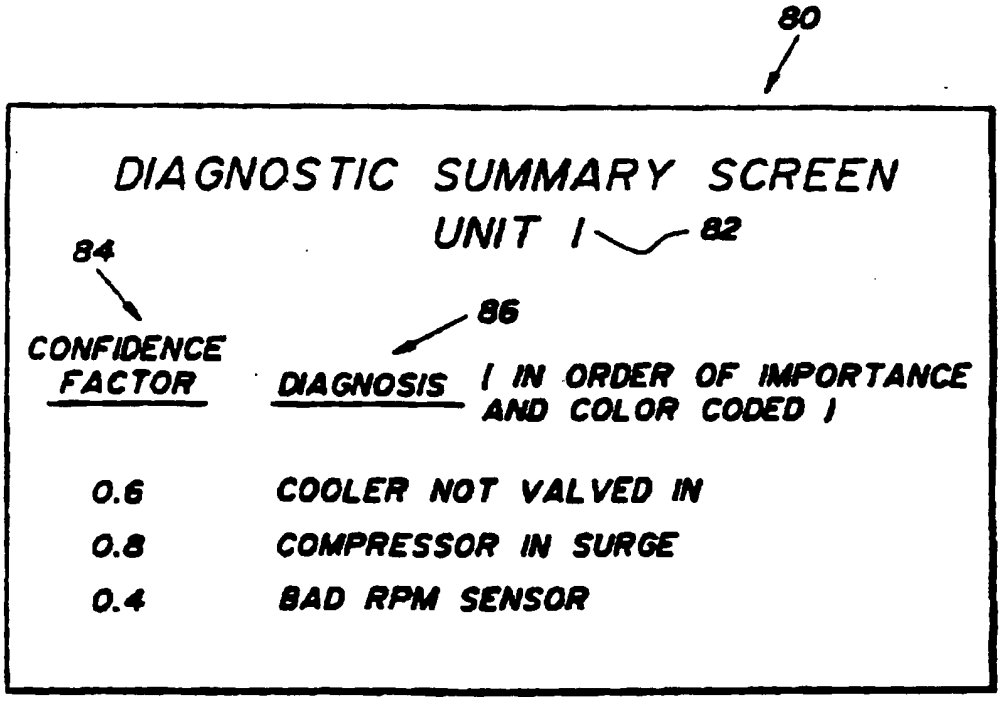
80
DIAGNOSTIC SUMMARY SCREEN
UNIT 1
82
84
86
CONFIDENCE FACTOR
DIAGNOSIS
1 IN ORDER OF IMPORTANCE AND COLOR CODED 1
0.6
COOLER NOT VALVED IN
0.8
COMPRESSOR IN SURGE
0.4
BAD RPM SENSOR

FIG. 5

INTERNATIONAL SEARCH REPORT

[redacted]on on patent family members

Inter[redacted]ion No
PCT/US [redacted]10998

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0528396	24-02-93	JP-A- 5210478	20-08-93
		JP-B- 7019199	06-03-95

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	ADVANCES IN INSTRUMENTATION AND CONTROL, vol. 48, no. PART 03, 1 January 1993 pages 1557-1564, XP 000428426 NAOKI URA ET AL 'REMOTE MAINTENANCE FUNCTION FOR DISTRIBUTED CONTROL SYSTEM' see the whole document ---	1,6
A	ZWF ZEITSCHRIFT FUR WIRTSCHAFTLICHE FERTIGUNG UND AUTOMATISIERUNG, vol. 87, no. 12, 1 December 1992 pages 659-663, XP 000327911 ADAM W. ET AL 'MODELLBASIERTES MULTIMEDIA-FERNDIAGNOSESYSTEM' see the whole document -----	1,6

1

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